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THE VIRGINIA JOURNAL OF SCIENCE

VOL. 2, NEW SERIES No. 1

THE PHYSICS OF ELEMENTARY PARTICLES

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Physical science from its earliest years has busied itself in an attempt to understand the structure of matter. Although the discovery and development of more specialized branches of physics have frequently held a brief spotlight, the structure of matter and the properties of its subunits have consistently been of foremost interest. The past decade has been no exception. Spurred on by the perplexing but fascinating problems in the world of elementary particles and by the advent of nuclear power, the physicist has brought the problem to its greatest peak of public and scientific interests. In a recent survey[1] of the present occupations of those physicists receiving their doctorates between 1936 and 1948, approximately half of those reporting a field of concentration listed nuclear, atomic, or molecular physics. It is this phase of contemporary physics which will concern us here with particular emphasis being placed upon elementary particle physics.

The outstanding advances recently made in other and borderline fields are by no means less interesting or less important. Biophysics, solid state physics, microwave spectroscopy, fluid dynamics—all of these fields boast significant achievements in the contemporary picture. Their development and the difficulties which they now face, however, are not markedly different from those in the physics of elementary particles. In his attempt to break matter down into its ultimate subunits, the physicist has discovered or created a need for no less than 12 such units in the form of charged or uncharged particles of finite or zero mass. (These so-called elecentary particles are listed in Table I.) The development which has brought about this current state of affairs is an interesting and instructive chapter in the history of physics.

Early Discoveries—The first milestones were the discovery of radioactivity and the identification of the electron as a particle carrying a negative electric charge. The phenomenon of radioactivity was discovered

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Editor's Note: In continuing the policy established by the Editorial Board to present in the first three numbers of each Volume of the Journal an article of general interest and progrss in the several fields of science, we have invited Professor Frank L. Hereford of the Rouss Physical Laboratory, University of Virginia, to contribute this article from the field of Physics.

1. Bernard C. Murdach & Marsh W. White, Physics Today, vol. 3, no. 9 (1950) pg. 20.

in 1896 by Becquerel; the electron was identified through the work of several men, J. J. Thomson in particular, at about the same time. We now know that the electron constitutes one of the products of radioactive emission, the beta-particle. The other entities sometimes emitted are alpha-particles (Helium nuclei) and gamma-rays (high energy photons). The photons can be thought of as the carriers of the energy associated with light waves, each carrying a very small quantum of energy. Considered as particles, they have zero mass and, of course, always travel at the velocity of light, usually denoted by c.

The next important contribution came in 1913 with Rutherford's formulation of the "nuclear model" of the atom, in which a heavy nucleus contains most of the mass and all of the positive charge. This central particle is surrounded by a sufficient number of negatively charged electrons to exactly compensate for the nuclear charge, Z. Thus Z is an integral multiple of the electronic charge. A second important nuclear parameter is the nuclear mass usually given as the total atomic weight, A. Beyond the recognition that A was usually equal approximately to an integral multiple of the atomic weight of the hydrogen atom, little was known of the properties of the nucleus at this time.

TABLE I

ELEMENTARY PARTICLES

Name	*Mass*	*Charge*	*Remarks*
Photon or gamma-ray	O	O	Quantum of radiation energy
Electron	$m_e = 9 \times 10^{-28}$gm.	$-e$	Also called beta-particle
Positron	m_e	$+e$	Also called beta-particle
Proton	1840 m_e	$+e$	Hydrogen nucleus
Neutron	1842 m_e	O	
Neutrino	O	O	Not yet observed
μ—meson	200 m_e	$\pm e$	Decays in 2×10^{-6} sec.
π—meson	300 m_e	$\pm e$	Decays in 10^{-8} sec.
Neutral meson	?	O	Existence tentative
τ—meson	1000 m_e	?	Existence doubtful
λ—meson	10 m_e	?	Existence doubtful
Negative proton	1840 m_e	$-e$	Hypothetical

During the following several years it became increasingly apparent that the laws and methods of classical Newtonian mechanics were totally incapable of coping with atomic phenomena, let alone specifically nuclear phenomena. We employ "atomic" to denote the physics of that portion of the atom exterior to the central nucleus, i. e., having to do with the orbital electrons and their motions and interactions.

Quantum Mechanics—It was at this stage in 1925 that the brilliant work of Bohr, Heisenberg, Schroedinger, and de Broglie culminated in the advent of quantum mechanics. This development was born of the realization that the very language of classical mechanics was largely meaningless in the domain of atomic phenomena. Classical physics attempted to specify the "state" of a physical system through the instantaneous values of the positions and momenta of all particles in the system. This procedure we now know to be quite meaningless, because any attempt to devise even an idealized experiment measuring simultaneously the precise values of position and momentum of a particle fails. Quantum mechanics tells us more specifically that the uncertainties in experimental values of position and momentum are related by the Heisenberg Uncertainty Relation,

$$\triangle p \cdot \triangle x = h/4\pi \qquad (1)$$

where we have written p for momentum, x for position and h for Planck's constant. This remarkable constant had been introduced previously in physics in Planck's investigation of radiation phenomena. Its numerical value of 6.6×10^{-27} erg-sec. is sufficiently small to render the limitations imposed by Eq. (1) negligible in macroscopic phenomena; however, in the physics of elementary particles it is a serious limitation.

In any case it appeared that a "physical state" as defined through the classical concept of the simultaneous values of the position and momentum of a particle had no basis in reality at all! The physicist had been obtaining theoretical results expressed in a language through which they could never be experimentally verified. In alleviating this difficulty quantum mechanics shifted physics to foundations involving strictly observable quantities. The classical equations relating supposedly precise values of physical variables were replaced by a"wave equation" as follows: Instead of associating a set of values with a physical variable, a mathematical operator was so associated, for example, an operator (which we shall call H) with the energy of the system. The physical state of the system was represented by a complex valued function, Ψ. Then the wave equation was written as,

$$H\Psi = E_n\Psi$$

and interpreted in the following way. The values En which allowed solutions of the equation, Ψ, with certain "golden" properties were, according to quantum mechanical laws, the "possible values" of the energy of the system. The laws provided further a method of computing

from Ψ the probability of observing any given value of the energy. Thus in a series of observations the number of times in which a certain value of a variable was observed could be directly compared to the probability of observing that value according to quantum mechanics.

It must be emphasized that this seemingly arbitrary procedure had actually been suggested by a sound line of reason based upon a careful analysis of the processes of measurement. The important point is that instead of predicting the outcome of an experiment in terms of (unobservable) precise values of variables, quantum mechanics furnished a set of possible values and a means of computing the probability of observing any one. The importance of this development and the success which it immediately achieved cannot be overemphasized. It represented the first successful attempt to untangle and analyze atomic phenomena on a quantitative basis.

Along with the development of quantum mechanics came an increased appreciation of the significance of Einstein's Theory of Relativity in the atomic domain. In the hands of Dirac and Pauli the union of these two theories brought about even more brilliant success, leading to the precise calculations of various atomic constants, and even forecasting the discovery of a new elementary particle, the positive electron.

The experimental discovery of this particle, which we now call the positron, came within a few years. It was identified by Anderson and his co-workers in examining the cloud chamber tracks of cosmic rays. This remarkable ultra-high energy radiation which falls upon the earth from outer space was to prove a storehouse of new elementary particles in the future.

The Nucleus—During this period there had been relatively little interest in purely nuclear phenomena. Although the disintegration of the nitrogen nucleus had been accomplished by Rutherford in 1919 by alpha-particle bombardment, significant progress seemed to stall until the discovery by Chadwick in 1932 of the neutron, a particle of approximately the same mass as the hydrogen nucleus (or proton) but carrying no electric charge. In the same year Cockroft and Walton produced nuclear disintegrations with artificially accelerated charged particles (Rutherford's projectiles had been radioactively emitted alpha-particles). The development of the cyclotron and Van de Graaff Generator followed and produced much higher energy beams of charged particles to be used in probing the nucleus. Accurate measurements of atomic weights led to information concerning nuclear structure and to the realization that protons and neutrons were the nuclear constituents.

The amazing properties of the nucleus gradually became apparent. In this region of space, hardly larger than that occupied by the electron, protons and neutrons of mass some 1850 times that of the electron are tightly packed in condensed phase. The tremendous forces effective there

derive from a conversion of a portion of the protons' and neutrons' masses into binding energy. The famous relation of Einstein's

$$E = Mc^2 \qquad (2)$$

stating the equivalence of mass and energy is indispensable in a quantitative analysis of nuclear phenomena. The exact nature of these nuclear forces remains today among the foremost unsolved problem in physics.

During the early 1930's a number of clues were uncovered bearing upon the problem. The nuclear forces were apparently short range forces, the nuclear particles only showing attraction within about 2×10^{-13} cms. of one another. The total binding energy of a nucleus was obtained through Eq(2) as the energy equivalent to the difference between the observed atomic weight and the sum of the masses of its protons and neutrons in separate unbound states. This binding energy was found to be proportional to the number (N) of protons and neutrons in the nucleus. which fact suggested that the forces had a saturation property. For if a nuclear particle were attracted strongly to every other particle in the nucleus the number of interacting pairs and hence the total binding energy should be proportional to N^2. Apparently the interaction of a single particle became saturated after interaction with a limited number of its neighbors. No known type of force had these properties.

At about this same time the nuclear physicist was faced with another serious difficulty. Nuclear data had indicated that only protons and neutrons existed in the nucleus and that electrons could not by any means be among the constituents. One reason for this followed from the uncertainty relation. If an electron were confined within a nucleus to a $\triangle x \cong 2 \times 10^{-13}$ cm., then the uncertainty in the momentum according to Eq. (1) would prevent its being held within the nucleus by forces of the magnitude which had been indicated by experimental data. Such was not the case for protons or neutrons. As a result of their greater mass, their uncertainty in momentum, $\triangle Mv$, corresponded to an energy much less than that for the electron, and in fact less than the nuclear binding energy. Thus these heavier particles could be bound in such a small region of space while electrons could not. The difficulty was that although denied an existence in the nucleus, electrons had been observed to emerge in the form of radioactively emitted beta-particles. This process is generally referred to as beta-emission.

A further difficulty arose in connection with the balance of energy in this process. Whereas the beta-particles were emitted with energies distributed over a wide range, the loss of total energy of the nucleus in the process was constant from one emission to another. The Conservation of Energy, a prize principle of the physicist, seemed threatened. To remove both beta emission difficulties in a single blow, Fermi proposed a solution which also provided a theory of nuclear forces.

Fermi's Field Theory—Fermi proposed that in the process of interacting with one another the nuclear particles exchanged or shared elec-

tron-neutrino pairs with one another. Thus a new type of particle, the neutrino, was introduced. Its role in Fermi's theory will be evident in the following discussion. The electrons and neutrinos were to exist in the nucleus not as distinct particles but in a sort of virtual state in much the same way as photons exist in an electro-magnetic field. In fact the presence of the electron-neutrino pairs in this sense was referred to as an "electron-neutrino field". This idea can best be understood through analogy with the electromagnetic field. Two charged particles act upon one another through their mutual interaction with their electric field. Two nuclear particles were to act upon one another through their mutual interaction with their electron-neutrino field.

Suppose that in the exchange process one of these electron-neutrino pairs were to manifest itself as a distinct pair of particles and escape from the nucleus. Would not this event appear as beta-emission? The emission of the neutrino could serve to carry away the missing energy referred to above. Its presence according to Fermi had been missed by the experimental physicist because of the neutrino's complete lack of observable properties such as charge, mass, or magnetic moment. In fact, this amazingly elusive particle has escaped direct detection up to the present time. Thus the beta-emission difficulties were removed, though in a somewhat artificial fashion.

As regards the results of this theory in explaining nuclear forces through the exchange process, many of the properties of nuclear forces were properly predicted. However, the theory was incapable of reconciling the observed values of a number of variables. When the observed particle masses, probabilities of beta-emission, and other appropriate constants were fed into the mathematical scheme, the computed strength of the nuclear forces due to the coupling of the electron-neutrino field was too small by a factor of about 10^{12}.

Yukawa's Meson—It was at this stage of development in 1935 that a Japanese physicist, Yukawa, carried the field theory of nuclear forces a step farther. In particular, he modified the coupling field and forced it to yield agreement among the experimental facts. In so doing he found that a new type of elementary particle was required to play the role of the exchanged particle in the interaction between two nuclear particles. According to Yukawa this particle which we now call the meson, should have a mass about 200 times that of the electron and should be radioactive, disintegrating into an electron and a neutrino. The mathematical formalism of this theory succeeded in predicting the short range and saturation properties of the nuclear forces. In addition through the disintegration of the new particle into an electron and neutrino, the process of beta emission was accounted for. It was possible to compute the probability of beta emission through computation of the probability of a meson disintegrating in the course of its exchange between nuclear particles.

For the physicist reader, a few details of this scheme will be of interest. In direct analogy with electromagnetic theory one might suppose the potential of the "nuclear force field" to satisfy the wave equation in empty space:

$$\Delta^2 \phi - \frac{1}{C^2}\delta^2\phi/\delta t^2 = 0 \qquad (3)$$

In association with a single nuclear particle at $r = 0$ a spherically symmetric solution to this equation (instead of omitting the time dependent factor) is,

$$\phi = \text{constant}/\ r$$

Realizing that this potential lacked the necessary short range property, Yukawa modified Eq. (3) as follows:

$$\Delta^2\phi - \frac{1}{C^2}\delta^2\phi/\delta t^2 + k^2\phi = 0$$

A spherically symmetric solution to this equation is:

$$\phi = \text{constant}\,\frac{e^{-kr}}{r} \qquad (4)$$

The additional constant, k, was then chosen in accordance with the experimental data which demanded a range of force potential of approximately 2×10^{-13} cm; thus,

$$\text{Range} \cong \frac{1}{k} \cong \quad 2 \times 10^{-13}\ \text{m}. \qquad (5)$$

Now according to quantum mechanics the range of the force to be associated with a moving meson is connected with the mass of the meson through the relation,

$$1/k = h/2\pi mc$$

From (5) and the known values of h and c one finds:

$$m = 200 \text{ electron masses.}$$

The mathematical formalism of the theory also accounted for the process of beta emission in a fairly quantitative fashion.

A number of essentially mathematical difficulties, however, were apparent and are today among the theoretical physicist's most persistent headaches. In particular the energy of interaction of a pair of particles diverges to infinity with decreasing distance between the particles. The empirical existence of nuclei with finite radii prohibits this on scientific grounds; it would be prohibited nevertheless by common sense. The theory was a signal success, however, in a field where little other than confusion had existed previously.

Two years after Yukawa's work was published, cosmic rays again proved their fruitfulness when Anderson at the California Institute of Technology and Street and Stevenson at Harvard concurrently discovered

the meson. Once again the clues were found in cloud chamber photographs of cosmic rays. We know now that some 80% of the cosmic rays reaching sea level are positive or negative mesons. This discovery was indeed an exciting one. However, difficulties began to multiply along with data bearing upon the properties of this new particle. It had the proper mass, and it did undergo beta-emission. It also exhibited, however, a distinct aversion to interacting strongly with protons, neutrons, or nuclei in general. Most mesons observed to come to rest in cloud chamber photographs underwent beta-emission within about 2×10^{-6} sec., whereas if they were the particles responsible for nuclear forces they should have been captured into nuclei in a much shorter time.[2] A *weak* meson-nuclear particle coupling seemed apparent.

On the other hand the mesons having a rather short lifetime could not have traversed great distances in reaching the earth from outer space, and must consequently have been produced through collisions of the incident primary cosmic rays with the atmospheric nuclei. By virtue of the mathematical theory of such collisions this process necessitated a *strong* meson-nuclear particle coupling. The dilemma is evident.

The Heavy Meson And Others—The dilemma remained until 1947 when a group headed by Powell of the University of Bristol announced discovery of another type of meson slightly heavier than the first type. This new particle was labelled the π-meson or the σ-meson depending upon whether it disintegrated into an old type meson (now called the μ-meson) or was absorbed by a nucleus after coming to rest in matter. Both types (π and σ) are frequently referred to as π-mesons. Since this new type meson did interact with nuclei it showed good prospects of filling the Yukawa prescription.

Again cosmic rays had proved the donor in providing this much needed particle. The mesons were observed among cosmic ray tracks left in photographic emulsions which had been stored for several months at mountain level altitudes.

Up to this point only nature through her still unknown methods of producing tremendous cosmic ray energies had made mesons. Within another year, however, the giant accelerator programs which had been initiated throughout the country began to pay off. Mesons were produced artificially using 380 Mev alpha particles from the University of California frequency modulated cyclotron. The first mesons so produced were identified as heavy mesons through the same techniques which had been employed in their discovery by the Bristol group. It thus appeared that these new particles might solve many difficulties. They could be produced high in the atmosphere by the primary cosmic rays and could subsequently give rise to the μ-meson component through disintegration. However, such interpretations must be regarded as extremely tentative at the

2. Actually negative mesons were captured by the nuclei of heavy elements, but Yukawa's theory required capture in light elements also.

present time. In any case the artificial production of π-mesons opened new realms of nuclear research, and previous lists of nuclear reactions induced by proton, neutron, and alpha particle bombardment are now being supplemented by meson induced reactions.

The current picture has been confused somewhat by evidence for the existence of a number of other type particles. Within the past several months results at the University of California at Berkeley have suggested the presence of a neutral meson of as yet undetermined mass. It appears that even in this instance cosmic rays had yielded the first clue. One finds in a 1947 issue of Nature a single cloud chamber event obtained by Rochester and Butler which they interpret as evidence for a new type neutral particle. Whether or not this particle can be identified with the neutral meson of the Berkeley experiments is speculative at this time.

Numerous other cosmic ray investigators have reported various types of mesons of masses ranging from a few electron masses to about a thousand. A group of Russian workers have seen fit to announce the discovery of no less than ten such particles which they call varytons. Generally, however, the μ-meson and the heavier π-meson are the only kinds definitely established, although the existence of a neutral meson can scarcely be doubted.

In any event the discovery of so many "elementary" particles has brought about serious doubts as to just how "elementary" they really are. The neutron is known to undergo decay, for example, transforming into a proton and an electron. Fermi has recently proposed the possibility that mesons are pairs of nuclear particles (protons and neutrons) in a super condensed state, the relatively small mass being due to a tremendous binding energy. On the other hand Born has employed a quantum mechanical principle in an attempt to show that the mathematical formalism of elementary particle physics allows a considerable number of discrete mass values.

The ultimate solution to these problems lies in the hands of theoretical and experimental physicists. The former is meeting difficulties involving the divergence of computed properties of elementary particles to infinity; the latter finds need for gigantic 10,000 ton cyclotrons and synchrotrons to probe the smallest elements of matter. For each it has been necessary to resort to the immense in investigating the minute.

A NEW RESEARCH TOOL AND TECHNIQUE FOR THE BIOLOGIST[1]

ERLING S. HEGRE

Medical College of Virginia

The apparatus and technique to be described is intended to provide a new approach to the study of the anatomy of minute structures.

The objective and final product is a photographic record of undistorted serial sections at two micron intervals through a biologic specimen.

By projecting the finished film as a motion picture it is possible to follow the course and changing relationships of the component structures (as for example a blood vessel or nerve) from level to level in an uninterrupted sequence.

The operation and significant features of the mechanical equipment designed to produce such records will be explained after first giving a preliminary account of the process as it may be carried out manually.

The tissue to be studied, as for example a small embryo, is first impregnated with lead acetate, infiltrated with paraffin and mounted in an exposed position on a small paraffin block. With a sharp knife (razor blade) a section is cut through the specimen at any desired level. A solution of sodium sulphide is then applied to the exposed surface of the block. After a short interval (5 to 10 seconds) the solution is wiped off leaving the histologic details visualized by the lead sulphide precipitate and ready to be studied immediately or to be photographed.[2]

This procedure of exposing successively deeper levels and staining each in turn may be continued until the entire specimen has been examined.

Because of the absence of mechanical distortion, photographs of successive levels can accurately be superimposed. It is this feature which made it practicable to construct an apparatus which would automatically

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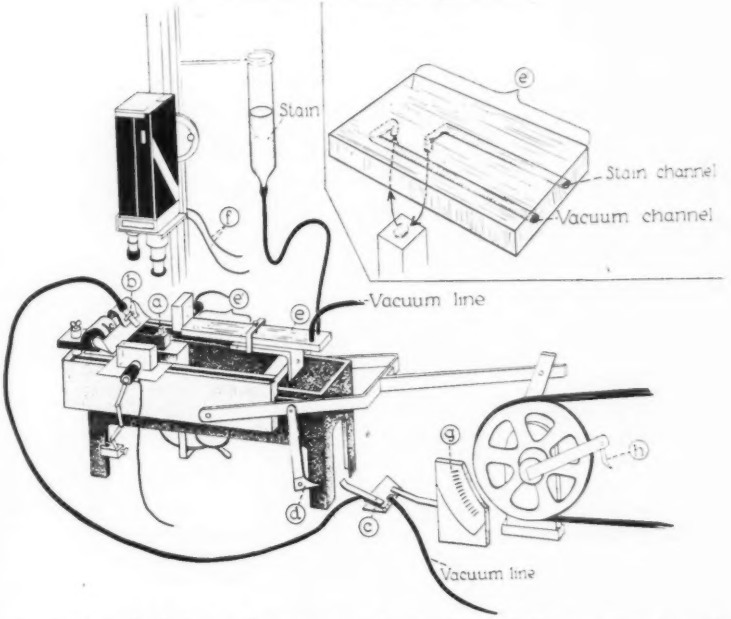
EDITOR'S NOTE: For this paper, presented at the Annual Meeting of the Academy, May 12, 1950, Dr. Hegre received the **J. Shelton Horsley Award.** This award is made annually in recognition of the "most highly meritorious paper" presented at the Annual Meeting.

1. This paper was presented before the Biology Section at the recent annual meeting of the Virginia Academy of Science held at Roanoke. It was accompanied by a motion picture illustrating the applications that have been made of this technique. Because of their nature these applications do not lend themselves to illustration in a published report. They must therefore be omitted in favor of a short written summary found in the concluding paragraphs of this paper.

2. A more complete description of this procedure, including directions for preparing the specimens can be found in the Anatomical Record, vol. 97, pp. 21-28, Hegre and Brashear, 1947.

FIGURE 1. Apparatus for making a photographic record of undistorted serial sections of biologic specimens.



cut, stain, and photograph successive levels through the prepared specimen. In the description to follow references will be made to the parts of the apparatus designated by letter as shown in figure one.

The tissue (a), an embryo such as was mentioned previously, is mounted in the usual manner in the vise of a sliding knife microtome. The knife is mounted at one end of the sliding carriage and is equipped with a suction tube (b) which will remove and dispose of each section as it is cut. The vacuum line is compressed by a normally closed clamp (c) which is released by a dog (d) at the proper interval.

The stain is conducted by gravity from a reservoir through a rubber tube to a channel in a plastic bar (e & e'). The fluid emerges through a small pore on the under surface of the bar where it slowly accumulates to form a hanging drop. A second and similar channel in this plastic bar (figure one, insert) is attached to a water siphon and will remove the excess stain.

The plastic bar is mounted on the sliding carriage in such a way that it will pass directly over the specimen with a clearance of a fraction

of a millimeter. Thus the stain will in turn be applied to the tissue, held in contact for a time and the removed at appropriate intervals of the cycle.

The specimen is illuminated by the filtered light from two spot lights.

A Cine Kodak special 16mm. motion picture camera is mounted above the block. The shutter release is electrically actuated as a revolving brush (h) passes over each exposed contact in an armature (g). Thus at the proper interval, a predetermined number of exposures can be made of each new level.

The whole apparatus is powered by a 1/3 H.P. electric motor on the input of an 800:1 reduction gear (not illustrated). The output is connected by pulleys and a V belt to the crankshaft which moves the arm attached to the sliding carriage.

An entire cycle is completed every 27 seconds and consists of cutting the section, removing the section by vacuum, staining the block surface, removing the excess stain from the surface and actuating the camera shutter.

Before mentioning some of the uses that have been made of this tool it should be pointed out that the essential procedure embodies a distinct departure from the usual method of preparing and studying serial sections; that is, the stain is applied not to the displaced section, but to the intact surface of the block. Attention can therefore be directed to the details on the exposed surface in their normal relationship to the remainder of the specimen. Furthermore, serial sections prepared by the routine methods always suffer some distortion due to compression during cutting or as a result of unequal spreading. Such inaccuracies do not occur with the present method.

Very thin sections are especially difficult to prepare by the usual method. The present equipment eliminates this problem in cases where a photographic record will suffice. Thus it is possible to study the undistorted structural details of a tissue at serial intervals of a fraction of a micron with ease.

This apparatus has been used to prepare photomicrographic records of serial horizontal and sagittal levels through embryos of various ages. The films are suitable for classroom projection as an aid to the teaching of embryology. They can also be used in making reconstructions with accuracy such as has not been possible by previous methods.

Some records are unique in that they have been prepared by placing the camera at an angle so as to record not only the successive levels but each in its normal relationship to the remainder of the specimen.

The technique has also been applied to the study of the microscopic structure of individual organs such as the lung of the adult.

NEAR BALANCE RECTANGULAR LATTICES

BOYD HARSHBARGER

Virginia Agricultural Experiment Station

INTRODUCTION

The development of statistical theory and its application to practical problems proceeded concurrently from the time when Pascal (1623-1662) and Fermat (1601-1665) became interested in certain problems that arose in connection with gambling. Down through the years researchers and professional men contributed numerous ideas, among which was the theory of large samples developed by Sir Francis Galton and Karl Pearson in connection with the laws of inheritance. R. A. Fisher pioneered the development of the analysis of variance, experimental designs, etc., and a chemist, William Gassett, contributed to the theory of small samples. The difficulties encountered in statistical inference have at least equaled those encountered in the development of mathematical theory and have provided equal opportunity for men of genius.

As to its present-day application, statistical theory is far reaching, with one of its chief uses in engineering and agricultural research. In nearly all scientific studies, the primary object is to make predictions. The experimenter makes observations and analyzes data primarily to be in a position to predict the outcome of similar tests or to form judgment as to the consequences of following or not following a certain course of action.

In much of experimental work we have to be continually making decisions under circumstances in which we cannot predict the outcome of an individual decision with certainty. In the great majority of cases, we do roughly attempt, in a qualitative way, to weigh the chances and make the best guess possible, but this is not good enough in modern research. We want to reason quantitatively about the risks involved. It is the purpose of this paper to present a new statistical design that in certain cases provides more efficient tests of significance than is available at present.

The theory of the experimental arrangement which is now called the lattice was first given by Cochran (1940) and Yates (1936, 1939, 1940). Because of the nature of the mathematical solution used in these designs, they were restricted to the cases where the number of varieties or treatments were perfect squares. In papers, Rectangular Lattices

(Harshbarger, 1947) and Triple Rectangular Lattices (Harshbarger, 1949), the author presents an extension of the lattices together with the general theory of the cases where the number of varieties or treatments are the product of two integers. An explicit solution is given for the case where the number of varieties is the product of two consecutive integers.

CONSTRUCTION OF NEAR BALANCE RECTANGULAR LATTICE DESIGNS

In the designs of Near Balance Rectangular Lattices each replication of k(k-1) varieties is divided into k blocks of k-1 varieties. The varieties are assigned to the incomplete blocks in such a manner that each of the k(k-1) varieties throughout the experiment occurs with exactly k(k-2) other varieties only once and never with the remaining k-1 in the k^2 incomplete blocks.

TABLE I

5x4 NEAR BALANCE RECTANGULAR LATTICE

Replication 1

Blocks					
(1)	0	2	3	4	5
(2)	6	0	8	9	10
(3)	11	12	0	14	15
(4)	16	17	18	0	20
(5)	21	22	23	24	0

Replication 2

Blocks					
(1)	0	6	11	16	21
(2)	2	0	12	17	22
(3)	3	8	0	18	23
(4)	4	9	14	0	24
(5)	5	10	15	20	0

Replication 3

Blocks					
(1)	0	12	23	9	20
(2)	21	0	18	4	15
(3)	16	2	0	24	10
(4)	11	22	8	0	5
(5)	6	17	3	14	0

Replication 4

Blocks					
(1)	0	17	8	24	15
(2)	16	0	23	14	5
(3)	6	22	0	4	20
(4)	21	12	3	0	10
(5)	11	2	18	9	0

Replication 5

Blocks					
(1)	0	22	18	14	10
(2)	11	0	3	24	20
(3)	21	17	0	9	5
(4)	6	2	23	0	15
(5)	16	12	8	4	0

For example, in a 5x4 Near Balance Rectangular Lattice, shown in Table I, in the first replication, variety (2) occurs in an incomplete block with varieties (3,4,5); in the second replication in an incomplete block with varieties (12, 17, 22); and in replications three, four and five in incomplete blocks, respectively, with varieties (16, 24, 10), (11, 18, 9) and (6, 23, 15). Variety (2) never occurs in an incomplete block with varieties (21, 8, 14, 20). In a test, varieties assigned to an incomplete block are randomized within the block and the incomplete blocks are randomized within a replicate. The zeros shown in Table I are for computational simplicity and do not appear in the design when placed in the field.

ANALYSIS OF NEAR BALANCE RECTANGULAR LATTICE DESIGNS

The mathematics for these designs is similar to that used in the development of the Rectangular Lattices. The resulting formulas for these designs increase in complexity as the number of replications increases until the point of using all possible replications is reached, which is the Near Balance Rectangular Lattice Design. At this stage the entire process of analysis suddenly becomes very much simplified. This simplification enters into all the calculations and enables much saving in time necessary for calculations. In addition greater efficiency over the randomized complete block is obtained as compared to other designs.

The symbols used in the design are defined as follows:

1. R_h is the sum of yields of the varieties for replicate h.
2. B_{hi} is the total of the yields of the varieties from the blocks i of replicate h.
3. T_{hi} is the sum of the yields from all replicates of the varieties listed in block i of replicate h.
4. $V_{adefg....}$ is the sum of the yields from all replicates of the variety with subscript adefg...
5. G is the grand total of the yields of all the varieties in the replicates.
6. $y_{adefg...}$ is the yield of a variety with subscript adefg... for a particular replicate.
7. k is the number of blocks in a replicate.
8. S_{hi} is the sum of variety estimates in replicate h and block i.

TABLE II

5x4 NEAR BALANCE RECTANGULAR LATTICE SHOWING SUBSCRIPTS

Blocks	*Replication 1*				
(1)	0	y_{12354}	y_{13542}	y_{14235}	y_{15423}
(2)	y_{21534}	0	y_{23415}	y_{24153}	y_{25341}
(3)	y_{31452}	y_{32145}	0	y_{34521}	y_{35214}
(4)	y_{41325}	y_{42513}	y_{43251}	0	y_{45132}
(5)	y_{51243}	y_{52431}	y_{53124}	y_{54312}	0

Blocks	*Replication 2*				
(1)	0	y_{21534}	y_{31452}	y_{41325}	y_{51243}
(2)	y_{12354}	0	y_{32145}	y_{42513}	y_{52431}
(3)	y_{13542}	y_{23415}	0	y_{43251}	y_{53124}
(4)	y_{14235}	y_{24153}	y_{34521}	0	y_{54312}
(5)	y_{15423}	y_{25341}	y_{35214}	y_{45132}	0

Blocks	*Replication 3*				
(1)	0	y_{32145}	y_{53124}	y_{24153}	y_{45132}
(2)	y_{51243}	0	y_{43251}	y_{14235}	y_{35214}
(3)	y_{41325}	y_{12354}	0	y_{54312}	y_{25341}
(4)	y_{31452}	y_{52431}	y_{23415}	0	y_{15423}
(5)	y_{21534}	y_{42513}	y_{13542}	y_{34521}	0

Blocks	*Replication 4*				
(1)	0	y_{42513}	y_{23415}	y_{54312}	y_{35214}
(2)	y_{41325}	0	y_{53124}	y_{34521}	y_{15423}
(3)	y_{21534}	y_{52431}	0	y_{14235}	y_{45132}
(4)	y_{51243}	y_{32145}	y_{13542}	0	y_{25341}
(5)	y_{31452}	y_{12354}	y_{43251}	y_{24153}	0

Blocks	*Replication 5*				
(1)	0	y_{52431}	y_{43251}	y_{34521}	y_{25341}
(2)	y_{31452}	0	y_{13542}	y_{54312}	y_{45132}
(3)	y_{51243}	y_{42513}	0	y_{24153}	y_{15423}
(4)	y_{21534}	y_{12354}	y_{53124}	0	y_{35214}
(5)	y_{41325}	y_{32145}	y_{23415}	y_{14235}	0

These estimates of population parameters must satisfy the relation $SW(y_{adefg\ldots} - m\,r_h - b_{hl} - v_{adefg\ldots})^2 + \frac{W'}{k-1} S\,B_{hl} - (k\text{-}l)m - (k\text{-}l)r_h - S_{hl}{}^2$, summed over and h (1) and is a minimum subject to restrictions $\Sigma r_h = O$, $\Sigma b_{hl} = O$ and $\Sigma v_{adefg\ldots} = O$.

The normal equations for evaluating the statistics are

$$\begin{gathered} k^2(k-l)m = G \\ k(k-l)m + k(k-l)r_h = R_h \\ (k-l)m + (k-l)\,r_h + (k-l)b_{hl} + S_{hl} = B_{hl} \\ k(W+W')m + W(b_{1a}+b_{2d}+b_{3e}+b_{4f}+b_{5g}+\ldots) + kWV_{aedfg\ldots} + \\ \frac{W'}{k-l}(S_{1a}+S_{2d}+S_{3e}+S_{4f}+S_{5g}+\ldots) = WV_{adefg\ldots} + \\ \frac{W'}{k-l}(B_{1a}+B_{2d}+B_{3e}+B_{4f}+_{5g}+\ldots) \end{gathered} \tag{2}$$

Equations from (2) lead in a fairly straight-forward manner to the Analysis of Variance Table III. In deriving this table it was found desirable to make use of Table II where the varieties are designated by use of subscripts so as to show their location in the various replications.

ESTIMATION OF W AND W′ AND THE CALCULATION OF ADJUSTED VARIETY MEANS

The estimates for W and W′ are derived from the Analysis of Variance Table. If the mean square resulting from the block effects is denoted by P and the mean square of the intrablock error by Q, then it can be shown that good estimates of W and W′ are

$$W = \frac{1}{Q} \tag{3}$$

$$W' = \frac{k-1}{kP-Q} \tag{4}$$

The adjusting of the variety means using both the inter- and the intra block information is accomplished by calculating certain constants. These constants are then subtracted from the variety means. If the variety means are arranged in order of Replicate 1, the first set of constants are subtracted from the means according to rows and the second set according to the columns. Then these variety means adjusted by the first and second set of constants are arranged as in Replicate 3 and the constants of set 3 are subtracted according to rows. Again the variety means adjusted by constants of sets 1, 2, and 3 are arranged as in Replicate 4 and these variety means are adjusted according to rows by the constants of set 4. This procedure of adjusting variety means is continued until all the replicates and sets of constants have been used. The means appearing in the last replicate are the adjusted variety means.

TABLE III

ANALYSIS OF VARIANCE

Source of Variation	Degrees of Freedom	Sum of Square	Mean Squares
Replication	$k-1$	$\frac{\Sigma R^2 h}{k(k-1)} - \frac{G^2}{k^2(k-1)}$	
Blocks	$k(k-1)$	$\frac{1}{k^2(k-2)}\left\{\Sigma\Sigma\ (kB_{hi} - T_{hi})^2 - \frac{k}{k-1}\Sigma(B_{1i}+B_{2i}+B_{3i}+\ldots+B_{ki})^2 - k(R_1^2+R_2^2+\ldots+R_k^2) + \frac{kG^2}{k-1}\right\}$	P
Varieties (unadjusted)	$k(k-1)-1$	$\frac{\Sigma V^2_{ade\ldots}}{k} - \frac{G^2}{k^2(k-1)}$	
Error (intra-block)	$(k-1)(k^2-2k-1)$	by subtraction	Q
Total	$k^2(k-1)-1$	$Sy^2_{ade\ldots} - \frac{G^2}{k^2(k-1)}$	

Another method is to list the variety means and then subtract from each the sum of the constants (C_{hi}) for the replication and block to which the variety belongs.

CONSTANTS

Set I

$$(W-W')\ [(k-2)W+W']\ (k_{11} - T_{11}) = C_{11}) \tag{5}$$

Set II

$$(W-W')\ [(k-2)W+W']\ (kB_{21} - T_{21}) = C_{21}) \tag{6}$$

Set III

$$(W-W')\ [(k-2)W+W']\ (kB_{31} - T_{31}) = C_{31}) \tag{7}$$

Set h

$$(W-W')\ [(k-2)W+W']\ (kB_{h1} - T_{h1}) = C_{h1}) \tag{8}$$

STANDARD ERRORS OF ADJUSTED VARIETY MEANS

To test the significance of two varieties, the standard error of their difference is needed. In the Near Balance Rectangular Lattice Designs there are two simple formulas for the standard error depending upon whether two varieties appear together in any one incomplete block or do not appear together.

The standard error of the difference between the means of two varieties occurring together in an incomplete block is

$$\sqrt{\frac{2}{kW}\left[1 + \frac{k-1}{k}\left(\frac{W-W'}{(k-2)W+W'}\right)\right]} \tag{9}$$

The standard error of the difference between the means of two varieties not occurring together in an incomplete block is

$$\sqrt{\frac{2}{kW}\left[1 + \frac{W-W'}{(k-2)W+W'}\right]} \tag{10}$$

The two above formulas can be weighted to give the average standard error which is

$$\sqrt{\frac{2}{kW}\left[1 + \frac{k}{k^2-k-1}\left(\frac{W-W'}{(k-2)W+W'}\right)\right]} \tag{11}$$

NUMERICAL ANALYSIS

To illustrate numerically the method of analysis for the Near Balance Lattice Designs, the analysis of a corn variety experiment is presented.

Since 20 varieties were to be tested in the experiment, a 5x4 Near Balance Lattice was used. The experiment was set up as in Table I and when placed in the field, the varieties were randomized within each block and the blocks within each replicate.

After the harvesting of the corn, the yields on a per acre basis were tabulated and compiled for computational purposes as shown in Table IV. The upper figure in each plot refers to the variety number while the lower figure is the variety yield in pounds per acre. The size of each plot was 2x10 hills.

The total yield of the varieties for the 5 replications are listed in Table V.

The calculations for the analysis of variance followed the formulas given in Table III. In order to compute the sum of squares for blocks corrected for varieties, it is convenient to form Tables VI and VII. Table VI shows the difference between 5 B_{bi} and T_{bi}. The block i totals shown in Table VII and the replicate totals are also used in the computation for the sum of squares for blocks.

TABLE IV

YIELD OF CORN VARIETIES BY REPLICATIONS

Replication 1

Blocks						Block Totals
		2	3	4	5	
(1)	0	66.1	78.7	73.9	83.2	301.9
	6		8	9	10	
(2)	59.5	0	68.6	65.0	87.8	280.9
	11	12		14	15	
(3)	86.0	97.5	0	97.4	95.2	376.1
	15	17	18		20	
(4)	77.0	76.8	75.5	0	80.7	310.0
	21	22	23	24		
(5)	89.5	83.7	77.2	83.5	0	333.9
Total					(R_1)	1602.8

Replication 2

Blocks						Block Totals
		6	11	16	21	
(1)	0	67.6	83.1	72.6	71.7	295.0
	2		12	17	22	
(2)	72.4	0	77.4	71.9	66.4	288.1
	3	8		18	23	
(3)	67.2	67.0	0	74.6	76.6	285.4
	4	9	14		24	
(4)	86.0	69.7	100.0	0	75.6	331.3
	5	10	15	20		
(5)	96.0	93.0	86.7	82.3	0	358 0
Total					(R_2)	1557.8

Replication 3

Blocks						Block Totals
		12	23	9	20	
(1)	0	74.2	64.2	60.4	71.5	270.3
	21		18	4	15	
(2)	68.6	0	76.9	67.4	67.6	285.5
	16	2		24	10	
(3)	68.1	63.6	0	61.1	75.7	268.5
	11	22	8		5	
(4)	75.8	68.8	66.3	0	83.0	293.9
	6	17	3	14		
(5)	58.8	73.7	71.2	86.4	0	290.1
Total					(R_3)	1403.3

Replication 4

Blocks						Block Totals
		17	8	24	15	
(1)	0	56.4	53.6	50.4	60.3	220.7
	16		23	14	5	
(2)	57.3	0	57.3	63.9	62.9	241.4
	6	22		4	20	
(3)	47.0	58.1	0	55.6	58.7	219.4
	21	12	3		10	
(4)	66.3	66.2	61.4	0	62.9	256.8
	11	2	18	9		
(5)	68.7	51.1	63.5	56.8	0	240.1
Total					(R_4)	1178.4

Replication 5

Blocks						Block Totals
		22	18	14	10	
(1)	0	76.2	72.2	87.8	75.0	311.2
	11		3	24	20	
(2)	79.5	0	75.1	68.6	84.6	307.8
	21	17		9	5	
(3)	80.8	78.7	0	62.7	88.9	311.1
	6	2	23		15	
(4)	66.8	66.4	75.9	0	86.0	295.1
	16	12	8	4		
(5)	68.4	77.6	70.0	66.3	0	282.3
Total					(R_5)	1507.5

TABLE V
VARIETY TOTAL YIELDS

Variety	Total	Variety	Total
2	319.6	14	435.5
3	353.6	15	395.8
4	349.2	16	343.4
5	414.0	17	357.5
6	299.7	18	362.7
8	325.5	20	377.8
9	314.6	21	376.9
10	394.4	22	353.2
11	393.1	23	351.2
12	392.9	24	339.2

TABLE VI

$kB_{h1} - T_{h1}$

i	T_{11}	$5B_{11} - T_{11}$	T_{21}	$5B_{21} - T_{21}$	T_{31}	$5B_{31} - T_{31}$
1	1436.4	73.1	1413.1	61.9	1436.5	−85.0
2	1334.2	70.3	1423.2	17.3	1484.6	−82.1
3	1617.3	263.2	1393.0	34.0	1396.6	−54.1
4	1441.4	108.6	1438.5	218.0	1485.8	−16.3
5	1420.5	249.0	1582.0	208.0	1446.3	+ 4.2

i	T_{41}	$5B_{41} - T_{41}$	T_{51}	$5B_{51} - T_{51}$
1	1418.0	−314.5	1545.8	10.2
2	1544.1	−337.1	1463.7	75.3
3	1379.9	−282.9	1463.0	92.5
4	1517.8	−233.8	1366.3	109.2
5	1390.0	−189.5	1411.0	.5

TABLE VII

BLOCK TOTALS FOR ALL REPLICATES

$(B_{11} + B_{21} + B_{31} + B_{41} + B_{51})$

i	Total
1	1399.1
2	1398.7
3	1460.5
4	1487.1
5	1504.4

The analysis of variance table for the experiment is shown in Table VIII.

In adjusting the variety means using the inter- and intra-block variances, the weights and correction terms are calculated from formulas (3) and (4) and formulas (5), (6), (7) and (8), respectively. W was found to be .062734 and W′ to be .013631. The correction terms are listed in Table IX. The unadjusted variety means, the appropriate corrections applied to each, and the resulting adjusted variety means are shown in Table X.

The standard error of the difference between the means of the two varieties

(1) occurring in an incomplete block is 2.760

(2) not occurring together in an incomplete block is 2.816.

The average standard error is 2.772.

TABLE VIII

ANALYSIS OF VARIANCE OF A NEAR BALANCE RECTANGULAR LATTICE EXPERIMENT

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	
Replicates	4	5711.12	1427.7800	
Blocks	20	1237.53	61.8765	(P)
Varieties (unadjusted)	19	4652.08	244.8463	
Error (intra-block)	56	892.65	15.9402	(Q)
Total	99	12,493.38		

TABLE IX

CORRECTION TERMS

i	C_{1i}	C_{2i}	C_{3i}	C_{4i}	C_{5i}
1	.724	.613	−.842	−3.117	.101
2	.697	.171	−.814	−3.341	.746
3	2.608	.337	−.536	−2.804	.917
4	1.076	2.161	−.162	−2.317	1.082
5	2.468	2.061	+.042	−1.878	.005

TABLE X

UNADJUSTED AND ADJUSTED VARIETY MEANS

Variety	Mean		Adjustment	=	Adjusted Mean
2	63.92	—	$(C_{11}+C_{22}+C_{33}+C_{15}+C_{54})$	=	64.36
3	70.72	—	$(C_{11}+C_{23}+C_{35}+C_{44}+C_{52})$	=	71.19
4	69.84	—	$(C_{11}+C_{21}+C_{32}+C_{43}+C_{55})$	=	70.57
5	82.80	—	$(C_{11}+C_{25}+C_{34}+C_{42}+C_{53})$	=	82.60
6	59.94	—	$(C_{12}+C_{21}+C_{35}+C_{43}+C_{54})$	=	60.31
8	65.10	—	$(C_{12}+C_{23}+C_{34}+C_{41}+C_{55})$	=	67.34
9	62.92	—	$(C_{12}+C_{24}+C_{31}+C_{45}+C_{53})$	=	61.86
10	78.88	—	$(C_{12}+C_{25}+C_{33}+C_{44}+C_{51})$	=	78.87
11	78.62	—	$(C_{13}+C_{21}+C_{34}+C_{45}+C_{52})$	=	76.69
12	78.58	—	$(C_{13}+C_{22}+C_{31}+C_{44}+C_{55})$	=	78.96
14	87.10	—	$(C_{13}+C_{24}+C_{35}+C_{42}+C_{51})$	=	85.53
15	79.16	—	$(C_{13}+C_{25}+C_{32}+C_{41}+C_{54})$	=	77.34
16	68.68	—	$(C_{14}+C_{21}+C_{33}+C_{42}+C_{55})$	=	70.86
17	71.50	—	$(C_{14}+C_{22}+C_{33}+C_{11}+C_{55})$	=	72.41
18	72.54	—	$(C_{14}+C_{23}+C_{32}+C_{45}+C_{51})$	=	73.72
20	75.56	—	$(C_{14}+C_{25}+C_{31}+C_{43}+C_{52})$	=	75.32
21	75.38	—	$(C_{15}+C_{21}+C_{32}+C_{44}+C_{53})$	=	74.51
22	70.64	—	$(C_{15}+C_{22}+C_{34}+C_{43}+C_{51})$	=	70.87
23	70.24	—	$(C_{15}+C_{23}+C_{31}+C_{42}+C_{54})$	=	70.54
24	67.84	—	$(C_{15}+C_{24}+C_{33}+C_{41}+C_{52})$	=	66.12

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A PUNCH CARD SYSTEM FOR THE BIBLIOGRAPHY OF ANALYTICAL CHEMISTRY

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INTRODUCTION

At one time or another every scientist has been faced with the great task which is involved in concentrating from the literature the information pertinent to his particular problem. This is a long job, and the amount of information which must be filed in one research laboratory often has such bulk that even to obtain information on one topic is time consuming. The increasing seriousness of this problem as the store of scientific literature grows has been viewed with alarm in many articles and editorials in recent years. The source of the difficulty has been attributed to the fact that the art of indexing and classifying information has not kept pace with the increase in the amount of information to be indexed, and the old methods are becoming less able to cope with the growing mountains of material. Dr. V. Bush, in the Atlantic Monthly of July, 1945[1] discussed this subject and suggested that someone perfect a mechanical memory called the "Memex" machine in which vast quantities of material could be stored and brought out at will with high efficiency, and under many classifications. Some work has been done on such a device, but until it is perfected other methods must suffice.

PUNCHED CARDS

GENERAL

The problem has been attacked, and in some phases partially solved by the use of punched cards. These are filing cards with which the operations of "sorting" and "selecting" may be done mechanically by virtue of information placed on them as code in the form of holes or slots. The sorting or selecting mechanism operates by responding to this code and accepting or rejecting any card during a given operation according to the position of the holes or slots. The more information a card can carry as code the more valuable it becomes as a unit in a filing system. This is because sorting or selecting can be done in terms of one class of information independent of the others and therefore each type of information

coded can be consulted as though the file were set up for that type. This completely eliminates the necessity for cross referencing.

Probably the best known system for making and handling punch cards is that of the International Business Machines Corporation, and it is widely used. However the equipment is too involved and expensive for use by a small laboratory. Another system of punch cards exists which fits very well the needs of a small organization or even an individual. This system involves the use of edge-punched and manually slotted cards, and because of its simplicity, nominal cost, and wide applicability it deserves more extensive use. Such cards can be obtained under the trade name of "Rocket" from The Charles R. Hadley Co., 330 North Los Angeles Street, Los Angeles, California, and under the trade name

FIG. 1

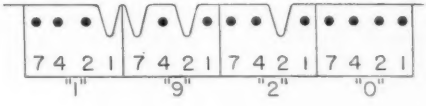


FIG. 2

FIG. 3

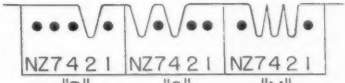


FIG. 4

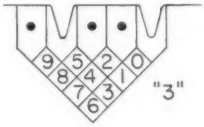


FIG. 5

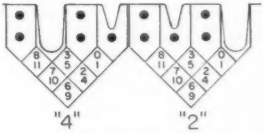


FIG. 6

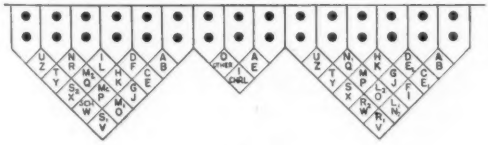


FIG. 7

FIG. 8

of "Keysort" from the McBee Company, Athens, Ohio, and have been discussed in several articles[2,3,4,5,6].

This paper is an attempt to summarize the techniques in use, to generalize on the possibilities for new techniques, and to describe one card form which should be widely adaptable.

METHODS

The basic principle of the edge notched punch card is that when a number of cards have holes punched in a certain place near the edge, and when cards corresponding to a given requirement have a slot cut so that this hole is opened to the edge (as shown in fig. 1) a needle may be passed through one of the holes in a stack of cards and the stack lifted, dropping out only those cards which have been slotted[2].

Direct Coding—A row of holes may be punched on each card and given different independent meanings, and can be slotted or not slotted in each position in accordance with the criterion for that hole. This has been termed direct coding and is the simplest method in use. If, for example, hole number 3 is slotted when the card is concerned with the element uranium, then by needling hole number 3 all of the cards on uranium can be obtained from the pack.

Field Coding, 7421 Type—Ingenuity soon led to improvements in the use of holes to gain versatility and to allow coding of numbers and letters. The idea of using several holes side by side combined in a "field" for coding was the basic step away from direct coding[3]. Numbers can then be coded by a system utilizing a field four holes wide with the holes labelled from left to right 7, 4, 2, and 1, respectively. By slotting one or more of these holes so that the sum of the numbers slotted represents the desired figure, digits from 1 to 9 can be coded (no slots representing zero), and all numbers up to 14. (See Fig. 2). By using several adjacent fields for the units, tens, hundreds, etc., large numbers can thus be coded.

There is, however, a loss in going from the direct coding to the above described field system. In direct coded cards all of the cards corresponding to a certain classification can be obtained by one pass of a needle; or if the cards are desired in a certain order of classifications they may be placed in that order by needling the holes in the appropriate order, which is of course a long business. These two operations are "selecting" and "sorting", respectively. The simple 7421 field does not allow the selection of numbers, but gains a great advantage in sorting efficiency.

It can be seen from the above example (Fig. 2) that if needles were inserted to drop out 1920, then along with 1920 would also come all four digit numbers with 1, 3, 5, or 8 as the first digit when followed by 9 as the second and 2, 3, 6, or 9 as the third. However this code does provide the ability to sort the cards into numerical order, which is done

by the following process. A needle is inserted into the hole at the extreme right and any cards which fall are placed at the back of the stack; the hole immediately to the left is now needled and the fallen cards placed at the back; this is continued until all the holes have been needled, when the pack will be found to be in numerical order, with the lowest numbers at the front.

Selectable 7421 Code.—In order to gain the ability to select, as well as sort, two more holes must be added to each field. These holes are labelled 0, and SF, the latter standing for "single figure". (Fig. 3). Then when 7, 4, 2, 1, or 0 is to be coded the SF hole is also slotted, and when 7, 4, 2, 1, or 0 is to be selected from a certain field two needles are used, one in the figure hole and one in the SF hole. The needle through the SF hole then prevents double figure cards from dropping.

Alphabetic Fields.— Coding of letters of the alphabet may be done by two methods, one of which adapts numbers, and the other, letters, to the job of being mnemonic devices[3,4]. In the numerical system the letters A through M are numbered 1 to 13, and slotted as such in a numbers field. To this field one extra hole is added, labelled N-Z, and the letters N through Z are also numbered from 1 to 13 and so slotted, but with the N-Z hole slotted also. This of course provides sortability but not selectability. (Fig. 4).

The mnemonic letter system also uses a field five holes long, the holes being labelled O, I, E, C, and B. Each letter is then assigned a slotting code as follows:

A — no hole slotted
B — B only slotted
C — C only slotted
D — C and B slotted
E — E only slotted
F — E and B slotted
G — E and C slotted
H — E, C, B slotted, and so on.

This also allows sorting of the cards but not selection of cards coded with a certain letter. It may be seen that the two systems are closely related.

A new and ingenious system of alphabetic and numerical coding was described by Cox, Casey and Bailey[5] which departed from previous practice in using a triangular code. By means of only two slots in a field five holes wide any digit from 0 to 9 could be coded and used either for selecting, or for sorting by the usual method. In each field the two holes are slotted whose diagonal columns intersect at the desired number. To select a given number two needles are inserted in the holes that would be slotted to code that number, and the pack is lifted, whereupon the selected cards drop out. (Fig. 5). This system is superior to the

earlier one in that more than two needles per field are never needed, and the fields are only five holes wide. It was further improved by the same workers by introducing the idea of using a double row of holes in conjunction with a triangular code. Two symbols can then be placed in each square of the field, thus greatly increasing the capacity. The desired square is then designated by the position of the slots as with the triangular code above, and if the upper symbol of the two occupying that square is meant, the left hand slot is to the first row of holes only, while if the lower symbol is desired, the left hand slot is deep. The right hand slot is, by convention, deep when the left slot is shallow, and shallow when the left slot is deep. (See Fig. 6).

By this system a numerical field is only four holes wide per digit, and yet it allows sorting, and selecting with one pass of the needles, using only two needles per field for the selection. Sorting is accomplished in a fashion similar to the one described above for codes using a single row of holes. A needle is passed through the upper hole at the extreme right and lifted; the fallen cards are placed at the back of the pack and the needle passed through the lower hole at the right, and the process repeated, needling the upper then the lower hole from right to left until the left hand side is reached, when the cards will be found to be in order. Selecting is done by needling the holes which would be slotted to code the card whose selection is desired.

With this system it is possible to make an alphabetic code without resorting to numbers as mnemonics, for with a field six holes wide, fifteen squares, or space for 30 symbols, are available, or if slight abbreviations such as grouping xyz together are not objectionable, a five hole field with 20 spaces may be used. Because of the variation in frequency of occurrence of the letters when they appear as the first, second, or subsequent letters of a word, Cox, Casey and Bailey[5], after studying letter frequencies for names, proposed an excellent breakdown of the alphabet, where the code varies for each of the first three letters of the name. With a code six holes wide, thirty positions, or four more than were necessary to code the alphabet were available. These they occupied by dividing the letter M into M_1, which are M's before Mc, Mc itself, and M_2 for M's after Mc, and by dividing the letter S into S_1, for S's before Sch, Sch itself and S_2 for S's after Sch. They found that in about 80% of names the second letter was one of A, E, I, O, C, H, L or R and that one of the group C, H, L, R occurred with about the same frequency as any of A, E, I, or O. Therefore they proposed a full code for the first letter, but an abbreviated three-hole-wide code for the second letter. In the case of the third letter a six-hole-wide code was proposed, but with different alphabetic distribution. Because of the frequent occurrence of E, L, N, and R as third letters, each of these was divided into two categories, E_1, E_2, L_1, L_2, etc., depending on whether the fourth letter of the word was from the first or second half of the alphabet,

respectively, thus obtaining somewhat finer sorting. (Fig. 7).

By this coding system cards may be sorted and selected by the same method described for its numerical analogue. This double-hole, triangular field coding system represents probably the best and most versatile system for numerical and alphabetical coding at present known for edge punched and slotted cards, and allows a large amount of information to be placed on a relatively small card.

Other Methods.—Other methods of coding exist, and can be devised. The same authors have proposed an improved six position selector code, one hole deep. They have also suggested that alphabetic sorting may be done by assigning numbers to equal alphabetic intervals.

Use of a double row of holes introduces the possibility not only of slotting shallow or deep, but also of cutting out the space between the two holes. However, cards slotted in this fashion do not drop clear of the pack when needled, and so lose to a large extent their advantage of convenience. (Fig. 8).

A system basically different from those above has been described by Mooers[7] and Wise[8], the mathematical theory of which has been discussed by the latter[9]. This difference is that more than one entry can be coded in a single field. Mooers' method is to use one large field and to assign to any word to be coded a given number of randomly chosen slotting positions. He states that a four-notch code in a field of 40 positions will allow up to seven coded ideas from a vocabulary of 90,000 coded ideas to be coded on each card. In this system, and that of Wise, extra or unwanted cards drop with those sought, but their number is small enough that they can be rejected by inspection. Wise uses a number of fields, with a number of slots in each, and each idea is assigned a code which gives it one slot in each field. He points out that in order to have maximum efficiency the number of fields should be so related to the number of ideas per card and the total number of available holes that on the average 37% of the holes should be slotted. These systems put few limitations on the material which can be coded. As well as words or numbers, chemical formulae and ciphers for organic compounds from the Dyson or the National Research Council system can be used. A full discussion of these codes will be found in a book edited by Robert S. Casey and J. W. Perry and soon to be published by the Reinhold Publishing Corporation.

THEORETICAL POSSIBILITIES FOR NEW METHODS

It is interesting to examine the methods of coding, sorting and selecting these cards which are now in use, and to try to devise new and better codes. One might casually guess that the efficiency and versatility of the cards might be improved indefinitely as better and better systems of coding were found. On second thought, however, one realizes that all

of the above described systems are merely mnemonic devices and that a card with a given number of holes punched in it has a maximum to the number of data which can be recorded on it. This maximum should be calculable, and attempting to do so led to the following results.

Let:

W stand for the width of the field in question expressed as a number of holes;

D stand for the depth of the field in question expressed as a number of holes;

N stand for the number of holes opened to the edge to code the data in question; (e.g., for a shallow slot N = 1, for a slot 2 holes deep N = 2, and if one of each of these is in the same field, N = 3);

K stand for the number of needles used for one pass, in selecting;

C stand for the available number of different choices of data to be coded when sortability *but not selectability* is required;

S stand for the available number of different choices of data to be coded when *both sortability and selectability* are required.

Direct Codes.—Each hole of a direct code may be considered as a field, where W = 1, D = 1 and N = 1, and therefore S = 1 and C = 2. If all the holes are independent of each other then the number of data which can be coded is equal to the number of holes on the card. It is possible to make the holes partially dependent, for example by deciding that "if hole number one is slotted indicating that the card refers to a book, then hole number three will be punched if it is over 500 pages long, whereas if hole number two is slotted indicating reference to a journal article then hole number three will be punched if it is over 5 pages long." This type of system can greatly increase the capacity of a direct type code, but from a strict standpoint it is not a true direct code, since the holes are not independent. It really amounts to using part of the possibilities in a field, since when this dependence exists N becomes 2, or else two passes are required for selection.

Field Codes—Sortable.—If selectability is not a requirement and sortability is desired then each different way that a field can be slotted represents one choice, and the following expression holds true:

$$C = (D + 1)^W$$

This is so because one position one hole deep gives two choices, slotted or unslotted; a position two holes deep gives three choices, and so on. This is expressed tabularly within reasonable limits of D, W, and C in Table I.

TABLE I.
VALUES OF C

	W = 1	2	3	4	5	6	7	8	9
D = 1	2	4	8	16	32	64	128	256	512
2	3	9	27	81	243	729			
3	4	16	64	256	1024				
4	5	25	125	625					

Field Codes—Selectable.—The number of different ways of slotting cards in a certain field so that they are selectable (and therefore also sortable) depends of course on the width and depth of the field, and also upon the value of N, the number of holes opened to the edge, and the number of needles used, K. Some thought will show that for a field of certain size (D and W constant) S can be calculated for various values of N; and for a certain N value, the maximum value of S equals the sum of S's obtainable with each value of K possible at that N value. An example will help to explain this. Assume we have a field where D = W = 3, and we wish to use N = 3. Then when K = 1, one of the three rows is slotted three deep and there are three selectable possibilities. When K = 2 one row is slotted two deep and another only one deep providing six selectable choices. Since two needles are involved none of the K = 1 cards will drop. When K = 3 all three holes are slotted one deep and one choice exists, and since three needles are used this does not conflict with any K = 1 or K = 2 choices. (See Fig. 9).

It is possible then to calculate tables of choices (S values) for different values of K and N when D and W are constant. Table II gives these values for D = 2, when W = 4, 5, and 6.

TABLE II.

	W = 4								W = 5										W = 6												
N →	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	11	12	K ↓
1	4	4							5	5									6	6											1
2		6	12	6						10	20	10								15	30	15									2
3			4	12	12	4					10	30	30	10							20	60	60	30							3
4				1	4	6	4	1				5	20	30	20	5						15	60	90	60	15					4
5												1	5	10	10	5	1						6	30	60	60	30	6			5
6																								1	6	15	20	15	6	1	6
Total	4	10	16	19	16	10	4	1	5	15	30	45	51	45	30	15	5	1	6	21	60	90	126	126	90	60	21	6	1		

It can be seen from this table that the maximum values of S occur when N is as close as possible to $\frac{DW}{2}$, i.e., when half the available holes are slotted. Calculations for other D and W values within the practical range confirm this. With this in mind it is possible to cal-

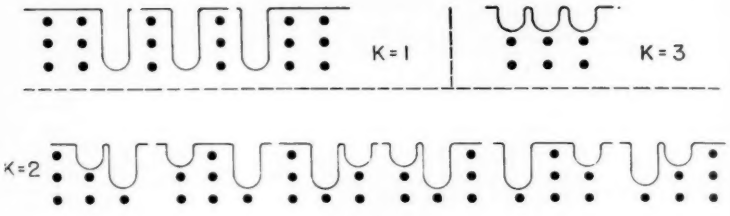


FIG. 9

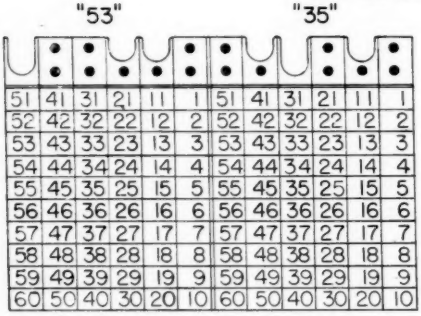


FIG. 10

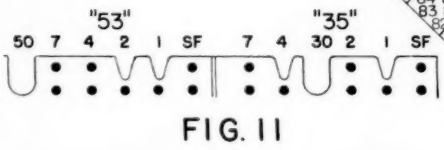


FIG. 11

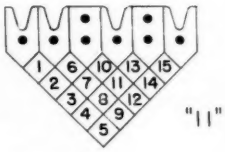


FIG. 12

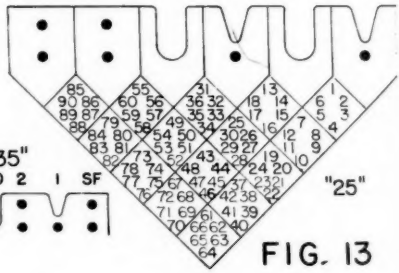


FIG. 13

culate and construct a table of maximum S values for different values of D and W. Table III is such a table. It is, in other words, a tabulation of the maximum number of data which can be placed in fields of different types, no matter what coding system is used, and still meet the requirement of selectability.

TABLE III.

MAXIMUM VALUES OF S

D \ W	1	2	3	4	5	6	7
1	1	2	3	6	10	20	35
2	1	3	7	19	51	151	
3	1	4	12	44	155	580	
4	1	5	19	85	331	1861	

It is interesting to note that in the alphabetic code of Cox, Casey and Bailey, in which W = 6 and D = 2, only 30 possibilities are utilized, whereas Table III gives a possible maximum of 151! By referring to Table II one can see that they are using all of the possibilities where W = 6, D = 2, N = 3, and K = 2. Even with N = 3 only half of the possibilities are being utilized, for with K = 3 thirty more are available. It is when N = 6 that S = 151.

While it is not difficult to calculate what the cards are able to do it is a task requiring great ingenuity to devise a mnemonic code to take advantage of their possibilities. It is of course not necessary to use a mnemonic; all of the slotting possibilities could be listed in a book with a meaning beside each, and this book referred to during coding or selecting. However, unless one is extremely crowded for coding space on the card the work and time saved by a mnemonic far more than makes up for the loss in efficiency of space utilization.

Examples of the type of mnemonic code that might be used to get more from a code where W = 6 and D = 2 have been worked out by the author for N = 4, and N = 5. The former of these is suggested as a simple, useful code, but the latter is given purely as an example.

Mnemonic Code for W = 6, D = 2, N = 4 (Fig. 10).— In order to code one of the symbols of the rectangular code of Fig. 10 the following conventions are followed:

a). The column in which the symbol appears is slotted deep.

b). The number of spaces down the column is indicated by imagining that the five remaining unslotted spaces are labelled 7421 SF, and by slotting two shallow holes to give numbers from 1 to 11 not including 10. Thus by reading 10 for 11, a code 10 deep and 6 wide may be obtained which gives sixty selectable and sortable choices.

While it is impossible to print 7421 SF on the card for this system

(since the location of these symbols changes with that of the deep punch) even a person who is unfamiliar with punched cards quickly grasps the method and after a little practice finds the system very simple. It may be used without actually printing the code on the card if it is considered that the position of the deep punch gives the tens digits on a field marked 5, 4, 3, 2, 1, 0 and the two shallow punches give the units digits on a 7421 SF field comprised of the remaining holes. (See Fig. 11). This is so easy to remember that printing the code is really superfluous.

This code is simple and direct and can be utilized with any cards having a double row of holes. If still further possibilities are desired in the same field fifteen more can be obtained by slotting four of the six positions one deep. This might be coded by allowing the unslotted positions to indicate the symbols on a triangular field. (Fig. 12). Since with this code the unslotted positions indicate the symbols, but selecting is done by needling the slotted holes, the numbers or symbols would appear in order opposite to the usual one, as in Fig. 12.

Still another fifteen possibilities may be utilized by slotting two positions two deep. The code here might be analogous to that described immediately above, except that the slotted holes would indicate the symbols and therefore the numbers would not be reversed.

All of these three methods may be used simultaneously in the field described, and they give the maximum number of selectable choices for W = 6, D = 2, and N = 4; however, to gain simplicity in sorting only the K = 3 or at most the K = 3 plus K = 4 systems might be used. This is because sorting can best be accomplished by needling the top row of holes from right to left in order and placing the fallen cards at the back after each pass, then repeating this for the deeper row of holes. This puts the K = 4 cards ahead of the K= 3 ones, and puts them in order using the codes shown in Figs. 11 and 13, but it mixes the K = 2 cards with the K = 3 cards, thereby causing complication if they (the K = 2 cards) are used.

Mnemonic Code for W = 6, D = 2, N = 6.— While the above code is simple enough to be useful, the example devised for N = 6 in the same field is one where the code is getting beyond the bounds of practicality. The greatest number of choices per K value can be obtained when K = 4, and therefore when two deep and two shallow punches are made. Symbols might then be coded by use of the following conventions:

a). With a triangular frame of 15 spaces (as in Fig. 13) the square of the frame in which the symbol lies is indicated by the position of the two sets of holes slotted two deep.

b). The remaining four sets of holes (two of which are to be slotted one deep) are considered to be a 4, 2, 1, SF, system by which it is possible to indicate any one of six symbols in each of the squares.

This provides the 90 choices predicted for K = 4, and still allows 60 other possibilities when K = 3, 5, and 6.

General.—It may be seen from the above discussion that while Table III gives the maximum number of selectable possibilities, a practical limit is imposed by the mnemonic code used. Thus the closeness of approach to the maxima of Table III depends on the capabilities of the code, and on the maximum number of needles and slots one is willing to use.

In judging the efficiency of a code it is useful to employ the concept of the number of combinations available per needle used in sorting. This was introduced by Wise and given the notation C_n, but in the notation of this article it would be $\frac{S}{K}$ since the C_n values for the entries in Table II can be obtained by merely dividing the numbers in the body of the table by their corresponding K value. It can be seen that for the code of Fig. 10, $C_n = 20$. This means that from a mechanical point of view this code is better than those where C_n is lower (e.g., Fig. 7, $C_n = \frac{30}{2} = 15$) and poorer than those where C_n is higher.

The question then arises, which of the several above described systems is best to use? The writer's experience indicates that for alphabetic and numerical fields the triangular codes of Figs. 6 and 7 are unsurpassed, except in cases where a number of mutually exclusive data are to be coded, (such as the journals on the card described below,) or where a finely dividable alphabet is desired. Then the rectangular code of Fig. 10 is probably best. This is of course a matter of opinion, and some users even prefer single depth codes. It is therefore desirable, when deciding on the code one is going to use, to examine all of the above described methods as well as those of Wise, Mooers, etc., and weighing simplicity against efficiency, pick the best ones for the case in hand.

Other basic changes in the method of slotting cards may be developed to gain versatility beyond that predicted above, such as the use of slanted slots, where the degree of slant determines the hole's meaning. Such changes however are difficult to foresee.

CARDS FOR BIBLIOGRAPHY OF ANALYTICAL CHEMISTRY

Types of Data.—In analytical chemistry the written portion of the cards should generally contain the following information:

Author's name(s) —Last name and all initials
Journal of Publication—Full name or authorized abbreviation
Date—Volume, page, month, year, and any other necessary subdivision
Title of article

Element or material for which analysis is being made
Material which is being analysed—Form, source
Method of analysis—Reagents, apparatus, technique
Results of analysis
Range over which method is applicable—Sensitivity and upper limit
Precision and accuracy of method

A fuller discussion of the classification of this material has been given by Patterson and Mellon[9] and anyone devising a code is well advised to refer to their work as well as the index entries of Chemical Abstracts and other reference works.

The following table indicates the desirability of coding each of these classes of information, (or the usefulness of the coded information) and the type of code required.

It is obvious that field type of code can be used only where data are mutually exclusive, that is, it could not be used for elements sought, since more than one element might be sought, but it could be used for journals, since a reference is to one journal per card.

With these factors in mind a card has been designed for use in the literature searching, abstracting, and indexing that is carried on in the Pratt Trace Analysis Laboratory, and has, it is hoped, been kept general enough in its design that it may be used by any laboratory or individual in analytical chemistry. It has been made by the Charles R. Hadley Company on cards 4 inches by 6 inches, a standard filing card size, using a substantial card material (ecru Index Bristol) punched with a double row of holes all around, and printed as shown in the photograph.

The following is a description of the coding system and methods used with this card at the Pratt Laboratory in a file which is predominantly concerned with the determination of minute traces of elements by colorimetric or spectrographic methods.

Author's Name.—The left hand edge of the card has three fields for coding the first three letters of the senior author's name. The first and second field are exactly as described by Cox et al. and utilize a 6-position triangular code for the first letter and a 3-position abbreviated code for the second. The code for the third letter has been abbreviated slightly to make it fit a 5-position field. Slotting, sorting, and selecting are done as described on page 7.

Date.—The first two fields at the left side of the top of the card are 4-position triangular numerical codes and are used to record the year of publication. Only the last two digits of the year are used; if a century other than the twentieth is involved the position immediately to the left of the year fields is slotted shallow.

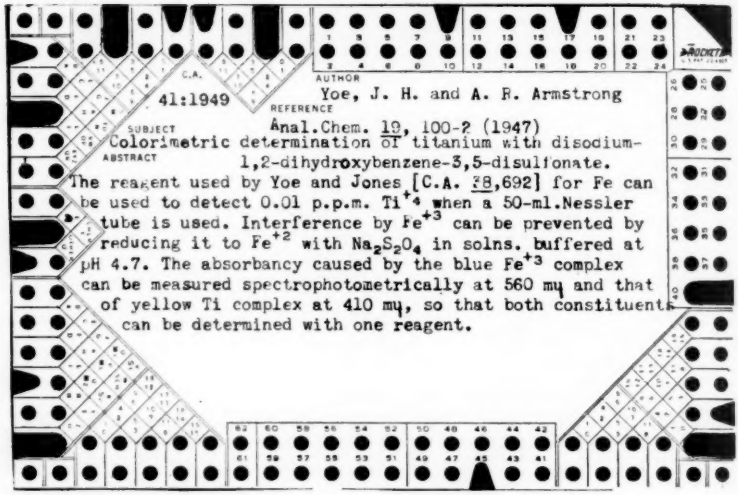
Journal.—The journal in which the article appears is coded in the triangular numerical field at the lower right hand edge of the card. Each journal (or small group of journals) is assigned a number as follows:

TABLE IV.

Information to be Coded	*Desirability of Coding or Usefulness When Coded*	*Type of Code Required*	
		Sortable	*Selectable*
Enough letters of author's name to ensure good sorting and reasonably small duplication on selection	Highest	Required	Required
Author's initials	Not very useful	Required	Required
Junior authors	Not very useful	Required	Required
Complete identification of journal (for at least all prominent journals)	Very high	Not necessary but useful	Required
Year of publication	Very high	Required	Required
Volume, page, month, etc.	Very low	.....	.....
Element sought	High	.....	Required
Material analyzed	Fairly high	.....	Required
Method of analysis	High	.....	Required
Reagents	High for some types of methods	Not necessary but useful	Required
Apparatus	Low	.....	.....
Results	Very low generally	.....	Required
Range over which method applies		.....	Required
Precision and accuracy	Low	.....	Required

0) Analytical Chemistry, formerly Ind. Eng. Chem., Anal. Ed.
1) Analyst
2) Zeitschrift fur Analytische Chemie
3) Journal Assoc. Official Agri. Chem.
4) Journal of the American Chemical Society
5) Journal of the Society of Chemical Industry, Chemistry and Industry, and Journal of the Chemical Society

FIGURE 14


C.A.
41:1949
AUTHOR
Yoe, J. H. and A. B. Armstrong
REFERENCE
Anal.Chem. 19, 100-2 (1947)
SUBJECT
Colorimetric determination of titanium with disodium-1,2-dihydroxybenzene-3,5-disulfonate.
ABSTRACT
The reagent used by Yoe and Jones [C.A. 38,692] for Fe can be used to detect 0.01 p.p.m. Ti+4 when a 50-ml.Nessler tube is used. Interference by Fe+3 can be prevented by reducing it to Fe+2 with Na2S2O4 in solns. buffered at pH 4.7. The absorbancy caused by the blue Fe+3 complex can be measured spectrophotometrically at 560 mμ and that of yellow Ti complex at 410 mμ, so that both constituents can be determined with one reagent.

6) Spectrochimica Acta
7) Journal of the Optical Society of America
8) Mikrochemie and Mikrochimica Acta
9) Journal of Research of the National Bureau of Standards
10) Nature, Soil Science, and horticultural journals in general
11) Journal of Industrial Hygiene and Toxicology, Biochemical Journal, Journal of Biology, and biological journals in general
12) Angewandte Chemie
13) Comptes rendus
14) Bulletin de la societe chimique de France and Bulletin de la societe chimique Belges
15) Russian journals
16) Japanese journals
17) Australian and New Zealand journals
18) Analytica Chimica Acta and Annales de Chimie Analytique
19) Miscellaneous

Elements Sought.—The right hand portion of the upper edge of the card with holes numbered from 1-24, is used for a direct coding of elements, the following elements being given the numbers shown by symbol:

1 As 3 Bi 5 Cl 7 Cr 9 Fe 11 Mg 13 Ni 15 Sb 17 Ti 19 V 21 U 23 Others
2 Al 4 B 6 Ca 8 Co 10 Cu 12 Mn 14 Mo 16 Pb 18 Sn 20 W 22 Zn 24 No Element

In order to code an element a slot is made down to the hole whose number corresponds to that element, whether it be shallow or deep.

Analytical Method.—The same direct method of coding is used for the analytical method involved using the upper portion of the right hand edge of the card (holes numbered 25-40). The methods are assigned to the following holes:

25 Flame photometry
26 Spectrography
27 Electrometry other than Polarography
28 Polarography
29 Solvent extraction
30 Distillation
31 Trace gathering by co-precipitation, organic reagents, etc.
32 Ashing and Combustion
33 Gravimetry
34 Radioactivity
35 Ion Exchange
36 Chromatography
37 Treatment of data
38 Volumetry
39 Nephelometry, Turbidimetry, or Fluorometry
40 Colorimetry

Material Analysed.—Along the bottom edge of the card, in holes numbered 41-54, and 62 the material being analysed, and some other general information is coded, as follows:

41 Foods and Nutritional Work	42 Metals
43 Photographic and Densitometric Work[1] Qualitative or Spot Tests[2]	44 Solutions
45 Excitation Sources[3] Visual Quantitative Tests[2]	46 Minerals and Soils
47 Spectrograph Design[1] Instrumental Methods[2] Amperometric Titration[3]	48 Biological Fluids
49 Electrodes[1] Mercury Electrodes[2]	50 Animal Tissue
51 Sample Preparation[1] Solid Micro-electrode[2]	52 Plant Tissues
53 Compounds—Organic	54 Compounds—Inorganic
55	56
57	58
59	60
61	62 Punched cards

The remaining positions and fields are not yet in use and are available for future needs, as yet unforeseen.

In either of the direct codes, that is, for methods or elements, it is possible to select all of the cards of one group by one of two methods. If the method or element is assigned a hole in the back row, then passing a needle through this hole and lifting will drop out all cards of this group. If the method or element has been assigned a hole in the front row, passing a needle through its hole will drop out cards of that group plus those corresponding to the hole behind it and these two groups must then be separated by needling the back holes. Although this is not a direct code in its truest form it is a method of coding the important data in a true direct code comprised of the deep holes, and then coding less important divisions in the shallow holes where they are slightly harder to reach and may sometimes be masked by a deep slot. If a mutually exclusive pair of data can be coded in each position the code is better, as the masking, resulting from the requirement for slotting one position both shallow and deep on one card, cannot occur.

General.—On the face of the card is indicated the position for typing or writing the author's name, the location of the reference, the subject or title of the article, its Chemical Abstracts number, and an abstract of it. Since the codes are in brown ink it has been found that typing or writing over them is quite legible and does not interfere with their use; however enough room is available on the front and back of the card that this is seldom necessary.

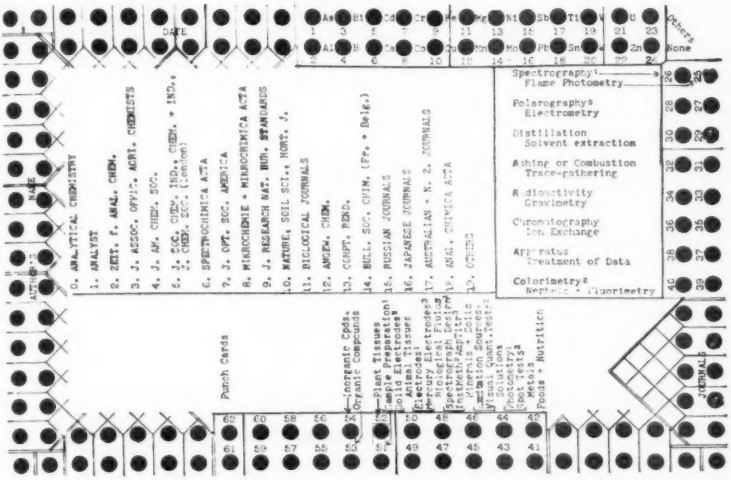
Fig. 14 shows one of the cards with data on it, and Fig. 15 shows a "key"card, with all of the information necessary for coding written on its face. Several of these key cards are kept with the file as a handy reference when coding.

The journals, elements, methods, and other categories listed above are those found to be important to the Pratt Trace Analysis Laboratory. Another laboratory might, of course, make a list quite different in its emphasis, reflecting the interests of the user. Since all the space on the card except the author and year codes can easily be adapted to almost any desired field of research, and since these two are generally necessary anyway, it is felt that this particular card may be found useful by other laboratories, especially in analytical chemistry. They may be purchased at a very reasonable price from The Charles R. Hadley Company.

Future of such a System.—In the year and a half that this system has been used the file has shown a constant growth and with this growth it has become more and more useful. It is hoped that in time it will cover our field of chemistry as exhaustively as could a bibliography and through its extremely fast reference possibilities will provide an immense saving of time to the succeeding generations of students and researchers who pass through a laboratory of this type.

1. These designations apply only when holes No. 25 or 26 are slotted (Spectrographic or Flame Photometric)
2. These designations hold only when hole No. 40 is slotted (Colorimetric)
3. These designations hold only when hole No. 28 is slotted (Polarographic)

FIGURE 15


Spectrography
Flame Photometry
Polarography
Electrometry
Distillation
Solvent extraction
Ashing or Combustion
Trace-gathering
Radioactivity
Gravimetry
Chromatography
Ion Exchange
Apparatus
Treatment of Data
Colorimetry
Nephelometry
Punch Cards
Inorganic Cpds.
Organic Compounds
Plant Tissues
Animal Tissues
Foods + Nutrition
Metals
Solutions
Visual quant. tests
Spectrograph. Designs
Spectrograph. Apparatus
Mercury Electrodes
Electrodes
Polarography
Apparatus
Titrations
Gravimetry
Colorimetry
Nephelometry
Fluorimetry
Ashing
Trace-gathering
Ion Exchange
Chromatography
Solvent extraction
Distillation
Flame Photometry
Spectrography
Treatment of Data
Apparatus
Electrometry
Polarography
Radioactivity
Gravimetry
Colorimetry
Nephelometry
Fluorimetry
Ashing or Combustion
Trace-gathering
Chromatography
Ion Exchange

ACIDITY-ALKALINITY IN THE ALIMENTARY CANAL OF TWENTY INSECT SPECIES

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INTRODUCTION

The importance of pH as a factor affecting the entrance of toxic substances into the tissues or body fluids of insects from the various digestive organs has been discussed in some detail by Hoskins (1940, p. 338) and pointed out by Waterhouse (1940, p. 8). Admittedly, most of the newer chemical insecticides are unaffected by the pH of the liquid in which they occur; but with many of the older insecticides, such as the arsenicals and nicotine compounds, their solubility is closely correlated with pH. Inasmuch as the stomach, or midgut, is the region of the insect digestive tract in which secretion of digestive juices and absorption of food products is thought usually to occur, the acidity-alkalinity of this region should be of special interest in toxicological work with stomach poison types of chemical insecticides.

Reported here are results of the preliminary phase of a study designed to determine whether there is a positive correlation between the toxicity of certain stomach poison insecticides and their solubilities at the pH existing in the insect midgut. For example, a poison showing maximum solubility at pH 9.0 would be expected to be more toxic to those insects having a strongly alkaline reaction in the midgut than to those in which the midgut reaction was acid. If any consistent relationship, either negative or positive, could be established between the theoretical and actual toxicities of certain stomach poison insecticides, then could not this knowledge be applied in a scientific approach towards finding new chemicals of insecticidal value?

The desirability of having exact, detailed data on the acidity-alkalinity occurring in the various regions of the insect digestive tract, especially the stomach, before beginning a toxicity study of this kind should be readily apparent. Although considerable data have been published on the pH of the insect digestive tract, in most cases single determinations were made on the contents of whole regions, and often the data were of uncertain reliability because of the use of faulty techniques. The purposes of this study were to obtain detailed information on the

pH in the various regions of the insect alimentary canal; to employ a glass-electrode technique for the determination of such values; and to obtain pH data on species of insects which have not been studied previously.

REVIEW OF LITERATURE

The published information on digestive tract reactions in insects of the orders Orthoptera, Lepidoptera, and Hymenoptera, are briefly summarized in Table 1. Unrecorded are the following results reported by Semans (1941) for the anterior end of the midgut in four families of Orthoptera: Acrididæ, pH 6.0; Gryllacridæ, pH 5.9; Tettigonidæ, pH 5.6; and Gryllidae, pH 5.6. Of particular interest in the Lepidoptera are the brilliant experiments of Lnderstrom-Lang and Duspiva (1935) in which it was clearly shown that the digestion of keratin in the clothes moth larva is made possible by the presence of an extremely active proteinase, and a reducing agent, and a pH of 10.0 or higher.

The most acid reaction yet reported for the insect digestive tract was found in the mid-stomach of certain species of Diptera. Hobson (1931) obtained the following pH values in *Lucilia sericata*: crop, 7.0 to 7.7; fore-stomach, 6.5 to 7.5; mid-stomach, 3.0 to 3.5; hind-stomach, 7.5 to 8.3; and hindgut, 8.0 to 8.5. Similar results were obtained by Waterhouse (1940) for nine other species of Diptera belonging to the genera *Lucilia, Calliphora, Chrysomyia,* and *Musca.* It is true that Randall and Doody (1934) have reported a pH of 3.0 for the junction of the stomach and hindgut of *Zootermopis angusticollis* (Isoptera), but the validity of this value is open to question. Conversely, other species of flies apparently have no such acid reaction in any section of the digestive tract. Values of pH ranging from 6.0 to 7.2 for the crop, 6.6 to 8.2 for the midgut, and 6.2 to 8.0 for the hindgut have been found in *Psychoda* and *Chironomus* (Crozier, 1924), in *Glossina* (Wigglesworth, 1929), in *Hypoderma lineatum* (Simmons, 1939), and in seven species of mosquitoes (Senior-White, 1926).

The remaining data, relative to insect digestive tract reactions, are rather meager and pertain to a number of insect orders. Values of pH for 25 species of Coleoptera have been reported by Swingle (1930 and 1931a), Kruger (1933), and Staudenmayer and Stellwaag (1940); three species of Hemiptera by Swingle (1931a); two species of Odonata by Swingle (1931a) and Kruger (1933); two species of Tricoptera by Kruger (1933); and a single species of Neuroptera by Swingle (1931a). Additional observations have been reported by Popow andGolzowa (1933) for two species of mosquitoes, a bed bug, a tick, and the human body louse.

Table 1.—Some pH values for the insect digestive tract as reported by different authors.

Insect*	Investigator	Saliva	Foregut	Midgut	Hindgut
Orthoptera					
Grasshoppers—17 species (avg.).A	Bodine (1925	5.5**	5.7	6.4	6.3
Grasshoppers— 2 species (avg.).A	Swingle (1931a)	— —	5.8	7.4	6.5
Crickets — 3 species (avg.).A	Swingle (1931a)	— —	5.4	7.3	6.6
Chinese mantis.A	Swingle (1931a)	— —	5.1	6.7	6.2
Wood cockroach.A	Swingle (1931a)	— —	6.3	7.2	6.9
German and American cockroaches.A	Wigglesworth (1927)	6.9	4.8-6.3	6.2	—
German cockroach.A	Day & Powning (1949)	— —	4.5-6.0	6.0	8.0
Walking stick	Castelnuovo (1934)	— —	8.0	7.3	7.3
Walking stick	Staudenmayer *et al* (1940)	— —	4.8	6.3	7.2
Lepidoptera					
Silkworm.L	Jameson & Atkins (1921)	— —	—	9.0-9.8	8.4
Silkworm.L	Shinoda (1930)	— —	—	9.0-9.8	—
Silkworm.L	Galzowa (1934)	— —	—	9.9-10.1	—
Clothes moth.L	Kruger (1925)	— —	—	6.8-8.4	—
Clothes moth.L	Duspiva (1936	— —	—	9.9	—
Wax moth.L	Duspiva (1936	— —	—	8.4	—
Oriental fruit moth.L	Swingle (1928)	— —	7.0	7.3	7.2
Codling moth.L	Marshall (1939)	— —	8.6	8.6	—
Catalpa sphinx.L	Swingle (1931a)	— —	9.2	9.5	—
Corn earworm.L	Swingle (1931a)	— —	8.2	8.0	—
Caterpillars—4 species (avg.)	Staudenmayer *et al* (1940)	— —	—	8.0	—
Hymenoptera					
Honey bee	Kruger (1925)	— —	—	8.4-9.8	—
Honey bee.A	Hoskins & Harrison (1934)	— —	—	6.3	5.5
Carpenter ant.A	Swingle (1931a)	— —	4.0	—	—
Wasp.A	Swingle (1931a)	— —	6.8	7.3	6.4
Hornet.A	Swingle (1931a)	— —	5.3	6.2	5.7
Bumblebee.A	Swingle (1931a)	— —	6.2	6.5	6.3

* A=adult; L= larva

** Fluid emitted from mouth

METHOD

The insect specimens were collected in their natural habitat, brought to the laboratory, and pH determinations made as soon thereafter as was possible. They were placed in cages and provided with food if determinations could not be made within a few hours after collection. Each insect was dissected by clipping off any large appendages such as legs and wings, exposing the entire body cavity by a longitudinal incision through the dorsal integument, and removing any tissues preventing quick access to the alimentary canal. Mixing of gut contents was prevented by either tying a silk thread tightly around the insect gut at appropriate places, or clamping the gut with tweezers. In obtaining a sample, a small incision of the gut wall was made with an insect pin or pointed glass rod, and the whole gut contents withdrawn by means of a micro-pipette and fine-pointed tweezers. Usually the samples obtained were moist enough to insure electrical conductivity, but sometimes it was necessary to add a trace of distilled water. This was done by first injecting the water into the insect gut at the desired point and then withdrawing it for addition to the sample. Complete determinations were made on each insect in those cases where satisfactory dissections were made and no delay in time occurred. Doubtful pH readings arising from such causes as too small a sample, eruption of the gut wall during dissection, or undue delay in completing the readings, were discarded.

In most cases the insect specimens selected for study were those containing considerable food in the digestive tract. Thus larger samples were available, and the condition of the digestive tract was considered as perhaps being comparable to that following ingestion of poisons with a normal diet.

The actual pH determinations were made with a Model G Beckman pH meter in combination with a calomel electrode and a one-drop, open glass electrode. Apparently there is only one reference in the literature (Duspiva, 1936) to the use of the glass electrode for determination of insect digestive tract pH, although this device has been used for pH determination of insect body fluids by Taylor and Birnie (1933), Taylor *et al* (1934), and Craig and Clark (1938). Duspiva (1936) has shown that small samples of high alkalinity may be affected from contact with carbon dioxide of the air, but the writer has found that high alkaline samples of the type obtained in this study are unchanged after exposure to air for as long as five minutes.

RESULTS

Table 2 lists the pH values obtained in the various regions of the alimentary canal of eight caterpillar species and one species of sawfly larva. All of the Lepidoptera larvae were feeding on plant leaves at the time of collection, except the corn earworm which was feeding on the

kernels of developing corn. The sawfly larvae were feeding on the leaves of dogwood. From 10 to 18 individual readings were made for each region of the digestive tract in the case of all species except the larvae of *Datana angusii* where each average figure was obtained from only 8 to 9 individual pH readings. The general average pH values obtained for the eight Lepidoptera species were: fore-stomach, 8.4; mid-stomach, 8.5; hind-stomach, 7.7; and rectum, 6.3 (Figure 1).

The pH values obtained in the various regions of the alimentary canal of ten species of adult grasshoppers and the adult stage of the American cockroach are shrown in Table 3. The grasshoppers were collected from their normal habitats and presumably had been feeding on grasses, clovers, sedges, or other similar plants. The American cockroaches were taken from a laboratory stock culture in which the food provided was dried dog biscuits, lettuce leaves, and water. Separate determinations were made on males and females in the case of four grasshopper species. Most average figures shown in Table 3 were determined from approximately 10 or more individual pH readings each; however, only 4 or 5 readings were obtained for each digestive tract region in the case of *Melanoplus bivittatus*. Readings on saliva were made from the liquid emitted from the mouth, which probably consisted of the secretions of the salivary glands plus regurgitated liquids from the crop. The general average pH values obtained for the ten grasshopper species were: saliva, 5.5; crop, 5.6; fore-stomach, 6.4; hind-stomach, 6.7; intestine, 6.7; and rectum, 6.2 (Figure 1).

The approximate locations in the different insect digestive tracts from which the samples were taken are indicated on the sketches shown in Figure 2.

Discussion

The one-drop glass electrode was found to be very satisfactory for measurement of insect digestive tract pH when samples of approximately 0.5 drop or larger were available. Rather rapid readings can be made with the aid of an assistant to dissect the insect specimens.

The acidity-alkalinity found in the digestive tract of adult grasshoppers as reported here is in fair agreement with the results reported by Bodine (1925) but somewhat at variance with those of Swingle (1931a). Critical comparison in either case is difficult because each author made only one reading for entire midgut and hindgut regions. Inasmuch as the results reported by Bodine are really pH values of the grasshopper gut wall, rather than gut contents, it is perhaps surprising that his data would agree so closely with those presented here. This would indicate that the ingestion of food has little effect on the acidity-alkalinity of the grasshopper digestive tract.

The pH values obtained in this study for the digestive tract of the American cockroach are similar to those reported by Wigglesworth

TABLE 2.—Values of pH obtained in the alimentary canal of eight species of caterpillars (Lepidoptera) and one species of sawfly (Hymenoptera).

Species		Crop	Stomach			Rectum
			Fore	Mid	Hind	
(Lepidoptera)						
Ceratomia catalpae (Bdvl.)	Range	—	8.5-9.8	8.6-10.1	7.0-8.7	5.6-6.7
	Avg.	—	9.0	9.3	7.8	6.1
Protoparce quinquemaculata (Haw.)	Range	—	8.3-10.1	8.4-9.9	7.3-8.6	6.5-7.3
	Avg.	—	9.3	9.2	7.8	6.8
Anisota senatoria (A. & S.)	Rnage	—	8.4-9.6	8.1-9.9	7.2-8.2	5.5-6.7
	Avg.	—	9.0	9.1	7.8	6.0
Hyhantria cunea (Drury)	Range	—	7.6-8.6	7.6-8.5	7.0-8.5	5.5-7.3
	Avg.	—	8.1	8.0	7.7	6.1
Datana angusii G. & R.	Range	—	7.9-8.8	8.8-9.6	7.8-8.8	———
	Avg.	—	8.5	9.0	8.3	
Archips fervidana (Clem.)	Range	—	7.5-9.9	7.5-9.3	7.2-8.3	———
	Avg.	—	8.3	7.9	7.8	
Heliothis armigera (Hbn.)	Range	—	7.1-9.1	7.0-9.4	6.6-7.8	5.8-7.5
	Avg.	—	7.8	8.0	7.2	6.6
Pieris rapae (L.)	Range	—	6.8-7.7	6.9-8.1	6.4-7.9	6.7-7.8
	Avg.	—	7.3	7.6	7.4	7.2*
(Hymenoptera)						
Macremphythus varianus (Nort.)	Rge.	5.1-5.9	6.3-7.2		6.3-7.7	5.7-6.4
	Avg.	5.5	6.6		7.1	6.1

* Determinations made on freshly voided faeces rather than rectal contents.

(1927) and Day and Powning (1949) for the German and American cockroaches. It is of interest that they found the cockroaches to have a pH of 6.0 to 6.3 in the crop after being fed on a strictly protein diet but a pH of 4.5 to 4.8 after they had fed on a carbohydrate diet.

Apparently only two of the Lepidoptera species reported in this study have been included in previous work on digestive tract acidity-alkalinity. The pH values obtained by Swingle (1931a) for the stomach contents of the catalpa sphinx and the corn earworm agree rather closely with those reported here. Also, the reaction obtained in the gut of *Pieris brassicae* by Staudenmayer and Stellwaag (1940) is in fair agreement

TABLE 3.—Values of pH obtained in the alimentary canal of ten species of grasshoppers and the American cockroach (Orthoptera).

Species	Sex		Saliva*	Crop	Stomach		Intestine	Rectum
					Fore	Hind		
Hippiscus rugosus (Scud.)	M	Range	5.1-5.7	5.3-6.0	5.9-6.8	5.9-7.0	5.8-7.1	5.6-6.6
		Av.	5.4	5.5	6.3	6.4	6.3	6.0
	F	Range	5.3-6.0	5.4-5.9	6.1-7.3	6.2-7.8	6.1-7.5	5.4-7.4
		Avg.	5.6	5.7	6.7	6.9	6.7	6.4
Melanoplus bivittatus (Say)	F	Range	5.2-5.5	5.3-5.7	5.7-7.1	5.9-7.5	6.1-6.7	5.6-6.3
		Avg.	5.3	5.5	6.6	6.8	6.4	5.9
Syrbula admirabilis (Uhler)	F	Range	5.2-6.4	5.3-6.4	5.9-6.9	5.9-7.6	5.6-7.6	5.2-7.7
		Avg.	5.5	5.6	6.5	6.8	7.0	6.6
Melanoplus differentialis (Thos.)	M	Range	5.1-5.7	5.0-5.6	5.6-6.5	5.8-7.1	6.6-7.4	5.9-7.1
		Avg.	5.3	5.4	6.0	6.5	6.9	6.7
	F	Range	5.0-5.7	5.2-5.9	5.7-6.7	5.8-7.2	6.0-7.3	6.1-6.9
		Avg.	5.4	5.4	6.1	6.7	6.8	6.4
Melanoplus femur-rubrum (Deg.)	F	Range	4.2-6.0	5.3-5.6	5.7-6.4	5.6-6.8	5.9-6.9	
		Avgg	5.4	5.5	6.0	6.1	6.5	
Schistocerca americana (Drury)	F	Range		5.2-6.0	5.9-7.4	6.3-7.5	6.5-7.5	
		Avg.		5.6	6.5	7.1	6.9	
Arphia xanthoptera (Burm.)	F	Range	5.3-5.6	5.4-5.9	6.3-7.5	6.2-7.7	6.4-7.6	5.5-7.3
		Avg.	5.5	5.7	6.6	6.8	7.0	6.3
Sparagemon planum Morse	M	Range	5.2-5.7	5.3-5.9	6.0-6.4	6.2-7.1	6.0-6.9	5.5-6.3
		Avg.	5.5	5.7	6.1	6.6	6.4	5.9
	F	Range	5.3-5.8	5.5-5.9	5.9-7.5	6.0-7.5	5.5-7.1	5.0-6.6
		Avg.	5.6	5.7	6.3	6.7	6.3	5.7

TABLE 3.—(*Continued*)

Species	Sex		Saliva*	Crop	Stomach		Intestine	Rectum
					Fore	Hind		
Chortophaga viridifasciata (Deg.)	F	Range	5.1-6.0	5.7-6.1	6.1-6.8	6.2-7.5	6.1-7.4	5.5-7.0
		Avg.	5.6	5.9	6.4	6.4	6.7	6.3
Dissosteira carolina (L.)	M	Range	5.4-5.8	5.4-6.1	6.0-7.2	5.8-7.3	5.8-7.6	5.2-6.3
		Avg.	5.6	5.7	6.2	6.5	6.6	5.8
	F	Range	5.2-6.0	5.4-6.0	6.0-7.2	6.4-7.4	6.4-7.3	5.4-6.9
		Avg.	5.6	5.7	6.7	6.9	6.8	6.2
Periplaneta americana (L.)	M	Range		4.4-6.3	5.7-6.3	5.8-6.7	6.8-7.5	7.1-8.0
		Avg.		5.2	5.9	6.2	7.1	7.6**
	F	Range		4.8-5.6	5.7-6.4	5.5-6.7	6.3-7.1	7.0-7.8
		Avg.		5.3	6.1	6.2	6.7	7.5**

* Fluid emitted from mouth.
** Determinations made on freshly voided faces rather than rectal contents.

FIGURE 1.—Average pH values for eight caterpillar species (A), a sawfly larva (B), adults of ten grasshopper species (C), and adults of the American cockroach (D).

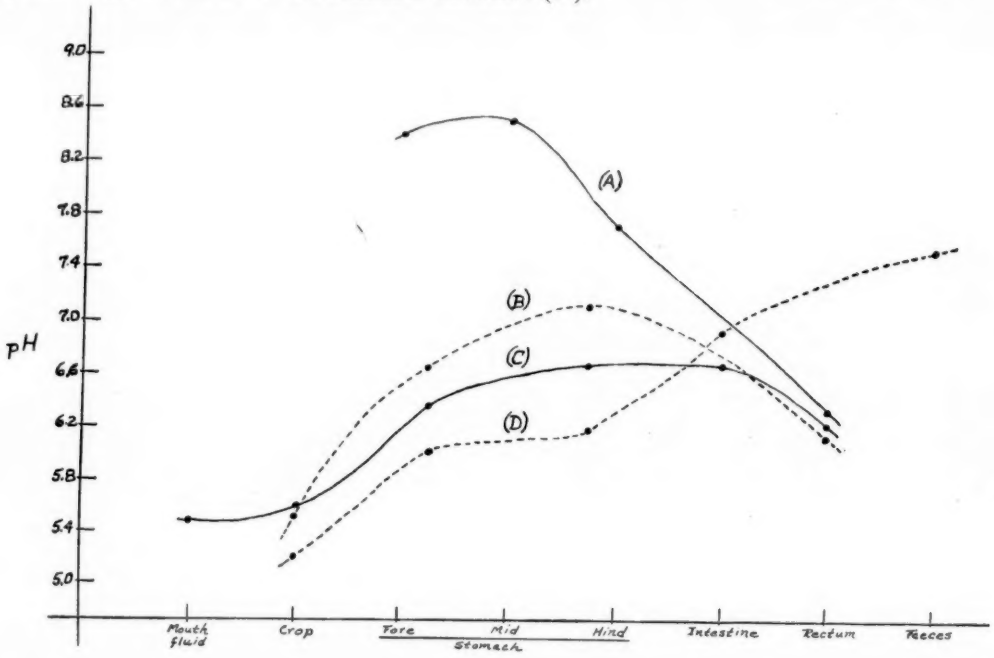
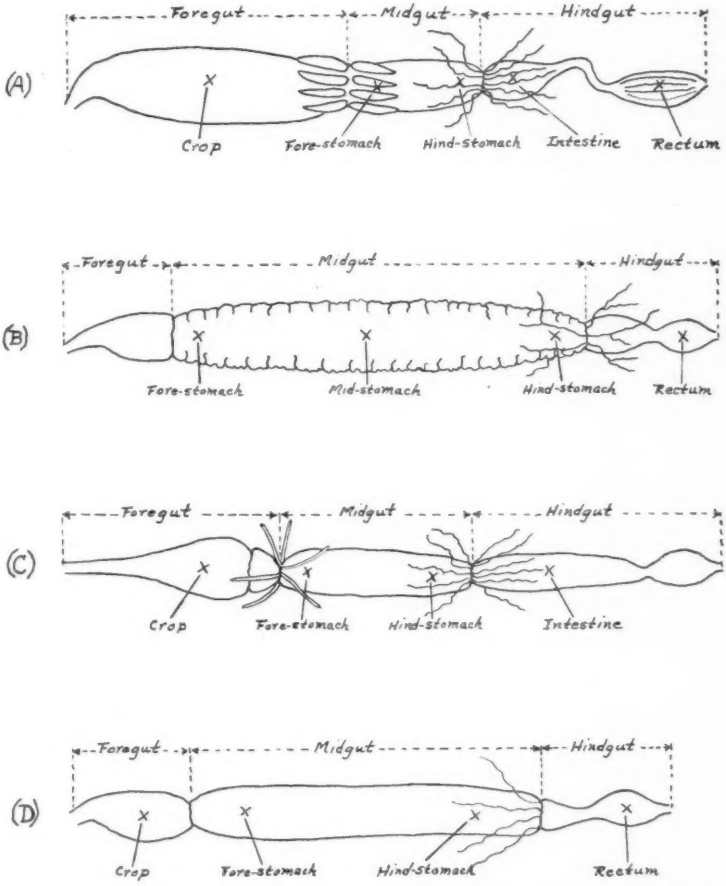


FIGURE 2.—Sketches of the alimentary canals of grasshopper (A), caterpillar (B), cockroach (C), and sawfly larva (D) showing locations from which samples were taken.



with that reported here for the mid-stomach of *Pieris rapae*. The species of caterpillars included in this study showed variations in individual readings ranging from 0.8 to over 2.0 pH units for each digestive tract region; thus it is evident that some selection of specimens would be

necessary if extremely high average pH values are to be obtained.

The results presented here on a sawfly larva are apparently the only published data on acidity-alkalinity in the digestive tract of phytophagous Hymenoptera. The pH values obtained, however, are in general agreement with those previously recorded for the honey bee (Hoskins and Harrison, 1934) and four other species of hymenopterous insects (Swingle, 1931a).

Attempts have been made to correlate alimentary canal pH values between different insect species from the standpoint of taxonomic relationship or type of food consumed. There are considerable data to support either of these theories, although exceptions to both exist. That the type of food ingested can affect the pH of the crop and fore-stomach has been shown by the work of Hobson (1931) on *Lucilia* larvae and that of Wigglesworth (1927) and Day and Powning (1949) on the German and American cockroaches. Apparently the stomach reaction of most insects is largely unaffected by the type of food consumed. Perhaps this is attributable to the buffering capacity of the various stomach secretions; at least strong buffering capacity has been shown in the Japanese beetle grub (Swingle, 1931b) and the honey bee (Hoskins and Harrison, 1934). On the other hand, it seems that the hindgut of phytophagous insects is more acid than the stomach, while the reverse is true in carnivorous or omnivorous insects. Those insects feeding on a predominately carbohydrate diet, such as the honey bee, apparently are similar in this respect to phytophagous feeders. This reaction in the hindgut has a plausible explanation in the decomposition of different foods and in the functioning of the insect malpighian tubules. The acidity of the hindgut in *Psychoda* and *Chironomus* was attributed by Crozier (1924) to a discharge of the malpighian tubules, and the high alkalinity of the hindgut in *Lucilia* was explain by Hobson (1931) as being caused by ammonia secretion. Kocian and Spacek (1934) have shown that the hemolymph of phytophagous beetles is more acid than that of flesh feeders.

ACKNOWLEDGMENTS

The writer wishes to express his appreciation to Miss Ann Martin and Mr. G. M. Boush for assistance in the laboratory.

SUMMARY

Data are presented on the pH values obtained in the various regions of the digestive tract of twenty insect species representing three orders of insects. All measurements of pH were made electrometrically by means of a one-drop glass electrode, with appropriate accessory attachments, in combination with a Model G Beckman pH meter. Insect specimens with considerable food in the digestive tract were selected for study, and the samples consisted of whole gut contents. The techniques employed in obtaining the insect specimens, preparing them for withdrawal of

samples, and removing the samples are described.

The average pH values obtained for ten species of adult grasshoppers (Orthoptera) were: fluid emitted from the mouth, 5.5; crop, 5.6; fore-stomach, 6.4; hind-stomach, 6.7; intestine, 6.7; and rectum, 6.2. Similar values for the adults of the American cockroach (Orthoptera) were: crop, 5.2; fore-stomach, 6.0; hind-stomach, 6.2; intestine, 6.9; and freshly voided faeces, 7.5.

The average pH values obtained for eight species of caterpillars (Lepidoptera) were: fore-stomach, 8.4; mid-stomach, 8.5; hind-stomach, 7.7; and rectum, 6.3

The pH values obtained on a single species of sawfly larva (Hymenoptera) were: crop, 5.5; fore-stomach, 6.6; hind-stomach, 7.1; and rectum, 6.1.

These data are critically compared with pertinent existing information on insect alimentary canal pH; and the possible relationships in digestive tract reaction between different insect species are discussed.

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ADDITIONAL NOTES ON VIRGINIA PLANTS NOT PREVIOUSLY REPORTED FROM MASSANUTTEN MOUNTAIN AREA

Quercus imbricaria Michx.

Left bank of South River near Grottoes, Rockingham County, Virginia, June 8, 1949.

This oak grows along the river bank and in adjoining fields for a distance of about two miles to Port Republic, Virginia. One large tree is on Grand Caverns grounds near Grottoes, Virginia. I have known it in this area since 1915.

Talinum teretifolium Pursh.

In old roadbed on red standstone near top of Massanutten Mountain, Page County, Virginia, south of Highway 211, July 3, 1948. Found at an earlier date in this area by Col. R. P. Carroll, V.M.I.

Viola conspersa Reichenb.

Rich, moist woods along Mine Run near Boyer Furnace, Powell's Fort, Shenandoah County, Virginia.

Chaemadaphne calyculata (L.) Moench

Roadside near swamp on top of Massanutten Mountain near Highway 211, Page County, Virginia, July 27, 1949.

Collected earlier in the season from this area by Col. R. P. Carroll, V.M.I.

(*Continued on Page* 61)

MESODON ANDREWSAE NORMALIS (Pils.) IN VIRGINIA

(Pulmonata, Polygyridae)

PAUL R. BURCH, *Radford College*

LESLIE HUBRICHT, 912 *Main St., Danville, Virginia*

Mesodon andrewsae normalis (Pils.) one of the largest land-snails in eastern North America, is common in parts of western Virginia although H. A. Pilsbry in his "Land Mollusca of North America" does not record it from a single locality. The authors during the past fourteen years have found it in nine counties. It was first taken in 1936 on the grounds of the Mountain Lake Biological Station of the University of Virginia at an elevation of 4,000 feet, identified by J. P. E. Morrison of the U. S. National Museum, and duplicates deposited in that museum. Since then it has been taken on every mountain visited in *Giles County* with an elevation of over 3,000 feet—Salt Pond, Doe, Big, Butte, Bald Knob, Bear Cliff and near Staffordsville and Kier. In *Craig County*, north of Giles and like it, bordering on West Virginia, on John's Creek Mtn. near Rocky Gap Fire Tower and near Captain. It has been sought in vain farther north. Farther southwest, in the Cumberland Mountains, it has been found in *Wise County* on Big Black Mtn. on Virginia Highway 160 near the Kentucky border and on Powell Mtn. at the High Knob Recreation Area near Norton. In the Blue Ridge Mountains it is known from as far north as the James River, having been taken in *Bedford County* near the Blue Ridge Parkway on Sharp Top and Headformost Mountains. Southwestwardly in the Blue Ridge it has been found on Poor Mtn., on Bent Mtn. near Carr (Twin Falls), and Buffalo Mtn., in *Roanoke County;* in *Montgomery County* (collected by Miss Lanora Geissler) near Shawville; in *Pulaski County* on Macks Mtn.; in *Patrick County along* U. S. 58 near Lover's Leap Wayside; in *Smyth County* on Iron Mtn. at Skulls Gap, 12 miles southeast of Chilhowie and at Comers Rock along the Grayson County line; in *Grayson County* on Buck Knob, 3 miles west of Longs Gap.

In 1949 fifty specimens were collected in a forested area about the size of a city lot near the Mountain Lake Biological Station during the night, where not even a dead shell to indicate their presence had been found the day before. This indicates that the species is highly nocturnal and that night is the best time to collect a good series. However, in the same vicinity in 1943 over 100 specimens for chromosome studies were

taken in three days. These last were found under and around logs recently felled for a power line right-of-way and along a two inch pipeline bringing water from a reservoir to the biology station.

This species seems to be limited to elevations above 2500 feet with most localities between 3000 and 4500 feet. It is found in company with *Mesodon zaletus, Triodopsis albolabris, T. dentifera, Mesomphix inornatus* and *Ventridens acerra.* Both juveniles and adults have been found eating the poisonus mushroom, *Russula emetica.* Further search may bring *M. a normalis* to light in other localities, especially in the Allegheny Mountains between Giles and Wise Counties.

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(*Continued from Page* 59)

Trientalis Americana (Pers.) Pursh.

Rich, moist woods along Mine Run, Powell's Fort, Shenandoah County, Virginia, May 18, 1948.

Phlox maculata var. *pyramidalis* Wherry

Meadow swamp near Oak Levels, Powell's Fort, Shenandoah County, Virginia, July 3, 1948.

LENA ARTZ, *Waterlick, Virginia*

News and Notes

(Editor's Note: News contributions should be sent to the person whose name appears at the end of the appropriate section.)

DONALD WALTON DAVIS

1882 - 1950

The Virginia Academy of Science has lost one of its most loyal supporters, one who has contributed much to its success.

Dr. Donald W. Davis, chairman of the Department of Biology of the College of William and Mary and a leader in science and education in Virginia, died at Newport News on June 30.

Born in Frazer, Pennsylvania, and receiving his Bachelor of Science and Doctor of Philosophy degrees at Harvard University, Dr. Davis was the senior member of the William and Mary faculty, which he joined in 1916. His broad knowledge of the field of biology was enhanced by studies at Columbia University and the John Innes Horticultural Institute, London. He taught at the University of California, Sweet Briar College, Clark College, Radcliffe College, and DePauw University.

He served as recording secretary of the Phi Beta Kappa Chapter at William and Mary for several years, and was also a member of the Genetics Society, the Genetics Association, the Society for the Study of Evolution, the American Botanical Society, and the National Association of Biology Teachers. Dr. Davis was instrumental in founding the Virginia Fisheries Laboratory and was proud of its accomplishments. He was a charter member of the Virginia Academy of Science, and served as its president from 1927 to 1928. He was greatly interested in the many activities of the Academy and especially in the re-establishment of its Journal.

As a token of the high esteem in which Dr. Davis was held by the members of the Virginia Academy of Science this issue of the VIRGINIA JOURNAL OF SCIENCE is dedicated to his memory.

THE 1951 MEETING AT LYNCHBURG

The Twenty-Ninth Annual Meeting of the Virginia Academy of Science will be held at Lynchburg College, Lynchburg, on May 10, 11, and 12, 1951.

Membership of the Committee on Local Arrangements:
Co-Chairmen: Dr. Harold H. Garretson, Ruskin S. Freer
Meeting rooms: Dr. John G. Mahan, V. Howard Belcher
Registration: Mrs. Ruth Bahous, Miss Mabel A. Sawyer
Housing: Grover W. Everett
Projection Equipment: Dr. M. Weldon Thompson
Publicity: Mervyn W. Williamson
Exhibits: Clyde E. Miller, Dr. John G. Mahan
Annual dinners: Miss Pearl G. Griffin, Miss Sallie Scott, Mrs. Alvern L. Rowell
Guest Speakers: Dr. Wilson F. Wetzler
Junior Academy: Donald D. Shipley, Chairman; Lawrence W. Sawyer, Registration; Albert H. Shuster, Jr., Housing; Laura Jeter Parker, Exhibits
Other members: President Orville W. Wake, Dean Fred Helsabeck, and Mrs. Christine K. Wells, Dean of Students

ANNOUNCEMENTS

The Virginian Hotel, 8th and Church Streets, is to be headquarters for hotel reservations. Their prices are: Single without bath, $2.50 and up; Single with shower, $3.25 and up; Double with shower, $6.00 and up. Banquet, Gymnasium, Lynchburg College, $2.50.

NOTES FROM THE SECRETARY

The April 1951 Issue of the VIRGINIA JOURNAL OF SCIENCE will contain the complete program and announcements of all the sections for the Twenty-Ninth Meeting of the Virginia Academy of Science.

This will be held May 10, 11, 12, 1951 at Lynchburg, Virginia, Lynchburg College being the Host Institution for this meeting. In order that this program can be properly prepared, the secretaries of all sections *must* have their completed program in the hands of Dr. Boyd Harshbarger, Editor-in-Chief, VIRGINIA JOURNAL OF SCIENCE, Department of Statistics, V.P.I., Blacksburg, Virginia not later than March 5, 1951.

Therefore, it will be necessary for the secretaries to invite papers for their respective programs as soon as possible. The members of the various sections are so designated by the respective section numbers in the Proceedings of the Roanoke Meeting.

FOLEY F. SMITH, *Secretary.*

MINUTES OF THE COUNCIL MEETING AT CHARLOTTESVILLE, NOVEMBER 12, 1950

The meeting of the Council and Officers of the Virginia Academy of Science was held in Room 24 of the Alderman Library, University of Virginia, on Sunday, November 12, 1950. Present were: Marcellus Stow,

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Edward Harlow, E. C. L. Miller, L. W. Jarman, Boyd Harshbarger, Harold H. Garretson, Ruskin S. Freer, Sidney S. Negus, Paul Patterson, Horton H. Hobbs, Jr., Ladley Husted, Guy W. Horsley and Foley F. Smith.

The meeting was called to order by President Horsley, and the first order of business was the report on the VIRGINIA JOURNAL OF SCIENCE by Dr. Boyd Harshbarger, Editor-in-Chief of the JOURNAL. He stated that the reason for the delay receiving the Proceedings of the Academy for this year was due to reorganization by the former printer, and consequent delay in preparation of the Proceedings, but he expected to have the Proceedings in preparation by the first of December. He also recommended that the bid made for printing of the VIRGINIA JOURNAL for next years be accepted. This is the same rate as last year, $3.50 per page with the exception that tables and complex equations, etc., would be raised to $6.00 per page. It was also recommended that the JOURNAL pay for one page of such tables, etc., and an additional five regular pages would be free to the author, with the exception that any pages over this amount would be paid for by the author at the regular rates.

Dr. Harshbarger also requested those present to assist in securing three more pages of advertising for the JOURNAL. It was properly moved, seconded and passed, to accept the printing bid for 1951, and Dr. Horsley extended the appreciation and thanks of the Academy to Dr. Harshbarger and his Editorial staff for their excellent work on the first volume of the VIRGINIA JOURNAL OF SCIENCE, New Series.

Dr. Stow, Chairman of the Long-Range Planning Committee, stated that he had had no formal meeting of his committee at this time. He, however, did make an informal report on the James River Project, and the status of the Monograph, "The James River Basin—Past, Present and Future." He stated that only 308 copies out of 2,211 copies of the Monograph had been distributed or sold, and expressed disappointment that members of the Academy had not as yet purchased copies.

The Chairman of the Research Committee was not present, but a request was made for publicity in the JOURNAL in order to secure more competing papers for the Horsley Award, and also to advise members about research funds available.

Edward Harlow reported on a meeting of the Southern Association of Science and Industry in Atlanta, in which they requested affiliation of other State Academies with the SASI, in order to further aid and coordinate research in the South.

He said that questionnaires had been sent to all the State Academies seeking information regarding their activities, membership, research projects, etc.

It was properly moved, seconded and passed, that the Academy pay for the necessary space in the JOURNAL for pictures and editorials rela-

Van Slyke

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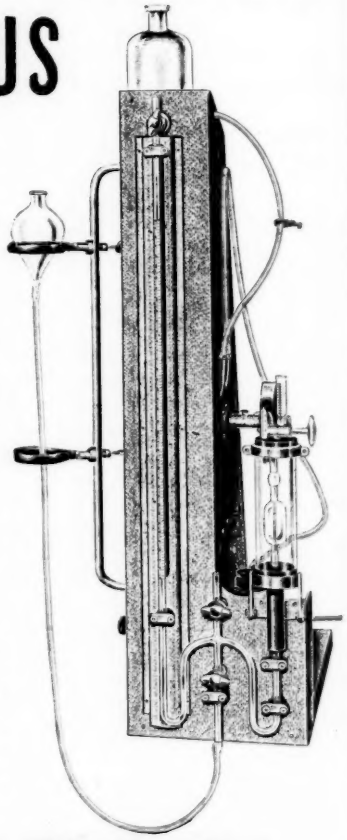
APPARATUS



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tive to the death of Dean Wortley Rudd and Donald W. Davis, both Past Presidents of the Academy.

The Council, in conforming with Section 7, concerning *Changes in the By-Laws* of the Virginia Academy of Science, properly moved, seconded and passed, the recommendation that the following changes be made. In Section 2, *Duties of Officers,* line 8 of paragraph 3 should be changed to read "all members whose dues are not paid by that date," the word *not* being substituted in the sentence. The second change, to delete sentence starting in line eight, paragraph 3, "He shall periodically supply the secretary of each section with a list of the paid-up members of their respective sections." The third change was to delete in line thirteen the phrase "with checks being countersigned by one of these." These changes were recommended and passed by the Council and publication of these changes is to constitute the notice of such changes being given in the VIRGINIA JOURNAL OF SCIENCE.

In conforming with Section 7, regarding changes in the By-Laws, the amended 3rd paragraph of Section 2 will now read as follows:

"(3) The Secretary-Treasurer shall keep a complete record of each annual meeting, and of other meetings held during the year by the Council, and shall prepare a report of their proceedings for publication. He shall keep the membership lists of the Academy in up-to-date fashion, shall promptly supply the Editor-in-Chief of the JOURNAL with the names of all new members, and shall likewise supply the Editor of the JOURNAL, on January 1, of each year, with the list of all members whose dues are not paid by that date. The Secretary-Treasurer shall receive all funds—except as provided below under Section (5), (2), shall disburse all funds as directed by the Council and approved by the President and/or Chairman of the Finance Committee, and shall submit at the annual meeting a written report of all receipts and disbursements. His annual report shall be accompanied by an audit by a recognized public accountant. He shall furnish quarterly financial summaries to the officers and to the members of the Council and of the Finance Committee. He shall be adequately bonded."

The Secretary-Treasurer gave a report on the financial condition of the General Funds of the Academy since the May meeting. With the expenses, and income received from current dues, the general fund balance is now $668.00 exclusive of $406.00 due to the VIRGINIA JOURNAL OF SCIENCE for pledges and subscriptions at $2.00 per member. The Research Fund account shows a balance of $824.00.

Dr. Garretson and Dr. Freer, Co-Chairmen of the Committee on Local Arrangements for the Lynchburg meeting in May, 1951, discussed plans for the meeting. Both the plans for the Junior Academy and Science Talent Search were discussed, and it was felt that adequate

preparations were being made for this meeting, to be held at Lynchburg College.

There being no further business the meeting adjourned at 5:30 P.M.

Respectfully submitted,

FOLEY F. SMITH

RESEARCH COMMITTEE

Encouragement of research in Virginia was one of the earliest declared purposes of the Academy. It is felt that the Research Grants-in-Aid and the J. Shelton Horsley Research Award, both instituted nearly twenty-five years ago, have contributed to this end. Greater interest and participation in both are urged by the Research Committee.

RESEARCH GRANTS-IN-AID

The income from the Academy's Endowment Fund is set aside each year to provide assistance to Academy members who submit to this committee worthy research problems for which financial aid is needed. Research grants during recent years have averaged from $75.00 to $100.00 each.

The applicant is requested to outline his problem and list the items for which assistance is required. The names and addresses of three persons who know his qualifications for scientific research should be submitted with the request.

Since funds are now available, the committee urges that applications be mailed at an early date to H. R. Hammer, P. O. Box 4178, Richmond 24, Virginia, so that they may be considered at its next meeting.

J. SHELTON HORSLEY RESEARCH AWARD

This award may properly be regarded as one of the most coveted prizes available to scientists in Virginia and accordingly might be expected to evoke general interest and widespread participation.

Unfortunately, interest had waned and participation had become so limited that last year, with the approval of the Officers and Council of the Academy, a different procedure was inaugurated. The cooperation of the Officers of each Section was solicited and authors were asked to submit their papers to the Secretaries of their respective Sections, rather than directly to the Research Committee. The Section Officers were further asked to serve as advisors to the Research Committee and to pass on to them papers which they deemed prizeworthy, even though they had not been formally submitted for the award.

This plan resulted in a gratifying increase in the number of papers which were considered. It is proposed to continue the same procedure, subject to suggestions and criticism on the part of Academy members, which the committee is most anxious to receive.

The only requirement for eligibility is that a paper submitted for the J. Shelton Horsley Research Award shall report original research by a member of the Academy and shall be presented at the May, 1951 meeting— H. R. HANMER, *American Tobacco Company, Richmond.*

SECTION NEWS

ASTRONOMY, MATHEMATICS AND PHYSICS SECTION

Leland Bradley Snoddy

1898 - 1950

It was with great regret that the members of this Section learned of the death of Professor Leland B. Snoddy at Charlottesville, November 12, 1950, after an illness of several months.

Professor Snoddy had been an active member of the Virginia Academy for many years, and was a former chairman of the Astronomy, Mathematics, and Physics Section. Born in Ohio, he attended the Universities of Kentucky and California, and received the Ph.D. degree from the University of Virginia in 1929. While studying at Virginia he was a member of the faculty of Lynchburg College. After receiving his degree he held an Edison Research fellowship and then served General Electric as a physicist. In 1933, Professor Snoddy returned to the University of Virginia, serving on the faculty of the School of Physics until his recent death. During the war years he was engaged in the program of research carried on at Rouss Laboratory under the auspices of the OSRD.

Professor Snoddy was a fellow of both the American Physical Society and the Optical Society of America, and was a member of many other honorary societies. His services as a consultant were eagerly sought by many institutional and government research laboratories. Although his interests were widespread, he was chiefly identified with the broad field of electromagnetic phenomena, and he was a pioneer in the development of linear accelerators.

In the passing of Professor Snoddy the Virginia Academy of Science has lost an outstanding member.

I. G. FOSTER, *Virginia Military Institute.*

BACTERIOLOGY SECTION

Virginia Branch, Society of American Bacteriologists
Fall Meeting, November 10, 1950, University of Richmond

12:30 Business Meeting, Room 102, Department of Biology, University of Richmond.
1:15 Lunch at the Refectory, University of Richmond.
2:15 Scientific Program:

1. Some Aspects of the Nutrition of *Endamoeba histolytica.*
   E. Clifford Nelson, D. Sc., Medical College of Virginia.
2. Behavior of *Endamoeba histolytica* in Culture with Viable and with Disintegrated *Clostridia perfringens.*
   Barbara H. Caminita, University of Maryland.
3. Some Factors Influencing the Culture of Protozoa.
   N. E. Rice, Ph.D., University of Richmond.
4. Some Observations on Lysogenic Bacilli.
   H. J. Welshimer, Ph.D., Medical College of Virginia.
5. Morphological Observation by Electron Microscopy of the Cave Bat Newcastle Disease Virus after Culture in Chick Embryos.
   Major Reagan, Professor of Virus Diseases, University of Maryland.
6. Film on Micromanipulation.
   A. S. Aloe Company, St. Louis.

J. DOUGLAS REID, *University Heights, RFD* 13, *Richmond.*

BIOLOGY SECTION

Mr. Orland E. White, Professor of Agricultural Biology, University of Virginia and Director of The Blandy Experimental Farm, Boyce, has been awarded a Fulbright Fellowship. He is now lecturing at University College, Mandalay, Burma.

Mr. Jaques Rappaport, formerly of the Department of Botany, Smith College, has assumed his duties as Plant Physiologist of The Blandy Experimental Farm and Associate Professor of Biology, University of Virginia. Mr. Rappaport received the M. Sc. degree from the Agricultural College at Ghent, and the Ph.D. from Dijon. He is especially interested in growth hormones and ovular tumors in incompatible plant crosses.

Dr. John Laurence McHugh of the Scripps Institution of Oceanography has been appointed Director of the Virginia Fisheries Laboratory. This was announced by the Board of Administration of the Laboratory on the occasion of the dedication exercises of the new physical plant. Mr. McHugh will assume his new duties in January. He will relieve Mr. Nelson Marshall who became Dean of the College of William and Mary in July, 1949, but continued to serve the Laboratory until a successor could be found. Mr. McHugh received his B.A. and M.A. degrees from the University of British Columbia and his Ph. D. from the Scripps Institution of Oceanography.

Symposium on Estuarine Ecology

A Symposium on Estuarine Ecology was held at Gloucester Point, Virginia, on October 12th. The symposium was arranged by the Atlantic Estuarine Research Society to sound the keynote for future research at

the new physical plant of the Virginia Fisheries Laboratory at Gloucester Point. Dr. R. E. Coker of the University of North Carolina and Dr. Waldo L. Schmitt of the U. S. National Museum served as co-chairmen, and the morning session was opened by Dr. Alfred C. Redfield of the Woods Hole Oceanographic Institution who spoke on "The Hydrography of Estuaries." Dr. Thurlow C. Nelson of Rutgers University speaking "On the Ecology of Some Estuarine Pelecypods with Especial Reference to the Oyster," and Dr. Paul S. Galtsoff of the U. S. Fish and Wildlife Service speaking on "The Physiological Problems in Estuarine Ecology" completed the morning session. In the afternoon Dr. Harold J. Humm of the Florida State University Marine Laboratory gave a paper on "The Role of Bacteria in Estuarine Ecology," Dr. A. G. Huntsman of the Fisheries Research Board of Canada a paper on "Population Dynamics in Estuaries," and Dr. R. V. Truitt of the Maryland Department of Research and Education spoke on "Fishery Products of Estuaries." Following an outdoor seafood supper the group reassembled to hear a talk by Dr. Bostwick Ketchum of the Woods Hole Oceanographic Institution on "The Tidal Flushing of Estuaries."

These sessions proved a major step in the current trend to recognize the problems of our estuarine sciences as distinct from oceanography and limnology. Following this symposium which it had sponsored, the Atlantic Estuarine Research Society held its semi-annual meeting. This

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society is a relatively small one, limited primarily to scientists currently doing research on estuaries in the Middle Atlantic coast area. The society's vigor is ample evidence of the growth of estuarine ecology.

LADLEY HUSTED, *University of Virginia.*

CHEMISTRY SECTION

During the long intermission since the July issue, a number of interesting items have been received and are included for the record.

From the Virginia Polytechnic Institute come the following notices of publications, sent at the request of the section editor.

P. C. Scherer and R. D. McNeer, "Controlled Fractionation of Ethyl Cellulose," *Rayon Textile Monthly,* 30, 8, 56 (1949).

P. C. Scherer and B. P. Rouse, "Mechanical Properties of High Polymers as Functions of Shape of Distribution Curve (III)—Cellulose Nitrate," *Rayon Textile Monthly,* 30, 11, 42 (1949).

P. C. Scherer and R. D. McNeer, "Mechanical Properties of High Polymers as Functions of Shape of Distribution Curve (IV)—Ethyl Cellulose," *Rayon Textile Monthly,* 31, 1 (1949)

C. K. Bradsher and F. A. Vingiello, "Aromatic Cyclodehydration. XXII. The Mechanism of the Cyclization of *o*-Benzyphenones., III," *J. Am. Chem. Soc.,* 71, 1434 (1949).

F. A. Vingiello and C. K. Bradsher, "4-Chloro-4′-t-butylebenzophenone and 4-Chloro-4-t-butyldiphenylmethane," *J. Am. Chem. Soc.,* 71, 3572 (1949).

Mr. George Buese and Mr. Joseph Shulman, graduate students, have been appointed research assistants to Dr. Frank A. Vingiello on a Research Corporation sponsored project concerned with the mechanism of aromatic cyclodehydration.

Dr. Robert C. Krug has received a grant-in-aid of $2,500 from the Research Corporation in support of a study of the action of reducing agents on organic compounds in liquid ammonia.

The new officers of the Virginia Blue Ridge Section include Clarence G. Haupt, Norfolk and Western Railroad, Chairman; Harriett H. Fillinger, Hollins College, Vice-Chairman; Ralph B. Long, American Viscose Corporation, Secretary; John F. Baxter, Washington and Lee University, Treasurer; Ashley Robey, Roanoke College, Recorder.

New officers of the Hampton Roads Section are C. S. Sherwood, III, Norfolk Division, W. M.-V. P. I., Chairman; George I. Earnest, Jr., F. S. Royster Guano Company, Chairman-Elect; Peter Eustis, Virginia Smelting Company, Vice-Chairman; K. Ellington, Monsanto Chemical Company, Secretary; William Francis, Naval Shipyard, Treasurer.

Dr. Lynn D. Abbott, Jr., associate professor of biochemistry at the

Medical College of Virginia, was one of a hundred reserve officers in the U. S. Navy, selected over the nation by the Office of Naval Research for a two-week scientific seminar held in Washington, D. C., in June. Selection was based largely on accomplishments of these officers in scientific research since the war.

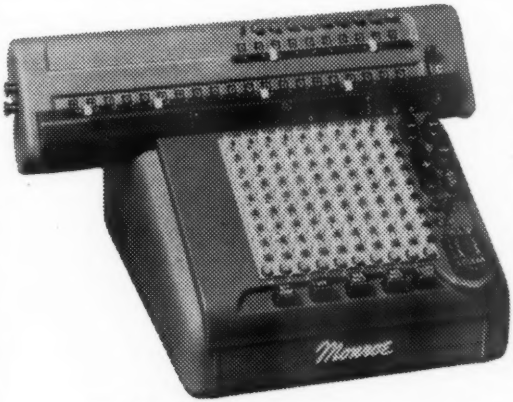
The Modern Chemistry Symposium, held at the Oak Ridge Institute of Nuclear Studies at the end of the summer was attended by J. W. Cole, of the University of Virginia; John F. Baxter, of Washington and Lee University; Mary Kapp, of Richmond Professional Institute; and the following from the Virginia Polytechnic Institute: F. C. Vilbrandt, F. W. Bull, W. L. McPherson, and R. E. Leed. Dr. Leed was at the Institute during most of the summer.

Dr. C. Clement French, formerly vice-president of Virginia Polytechnic Institute, was appointed dean of the Texas A. and M. College.

Among the papers presented at the Chicago meeting of the American Chemical Society are the following:

Max Erne, F. A. Ramirez, and Alfred Burger (University of Virginia) "Pyridine and Thiazole Derivatives as Pharmacodynamic Agents. 1-(Thiazolyl)-2-aminopropanes and Di-(4-thiazolyl) acetic Acid."

Jason M. Salisbury, James W. Cole, Jr., Lyle G. Overholser, Alfred R. Armstrong, and John H. Yoe (University of Virginia), "Determina-



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tion of Fluorine in Monofluorinated Organic Compounds in Air and in Water."

R. F. Conaway (E. I. du Pont de Nemours and Company), "Esterification of Cellulose."

C. W. Tait, R. J. Vetter, J. M. Swanson, and P. Debye (E. I. du Pont de Nemours and Company), "Physical Characterization of Cellulose Xanthate in Solution."

William J. Hart and Jack Compton (Institute of Textile Technology), "A Study of Soiling and Soil Retention in Textile Fibers. II. Kinetics and Mechanism of Primary Deposition of Grease Free Carbon Blacks on Cotton Fibers."

A. G. Richardson, J. Stanton Pierce, and E. Emmet Reid (University of Richmond), "N-Aryl-N′-Alklyoxamides for the Identification of Primary Alkyl Amines."

J. S. Tinsley, of the Hercules Powder Company, presided over the general section of the Division of Cellulose Chemistry.

The section editor would like to make these notes representative of the entire section, and to that end urges all readers to send in news of their own scientific activities and of any other events that come to their attention.—WILLIAM E. TROUT, JR., Box 168, *University of Richmond.*

EDUCATION SECTION

Citizen Education Project

High Schools in seven Virginia communities—Arlington, Martinsville, Norfolk, Norfolk County, Richmond, Suffolk and Williamsburg—are taking part in the Citizenship Education Project, a program planned by Columbia University with substantial financial support from the Carnegie Corporation. The project is designed to give students a knowledge of the principles of American democracy, attitudes affirming those principles, and skills in applying them in their daily lives. Two kinds of resources have been developed for the use of teachers in citizenship education. One of these is a set of digests of instructional materials; the other is a set of descriptions of laboratory practices. Organization guides for typical high school courses in American History and Civics have been developed to enable teachers to utilize these basic resources effectively. Tests prepared by the Project will be given three times during the semester as a control and check on the progress being made in individual classes.— FRANCIS G. LANKFORD, *University of Virginia.*

ENGINEERING SECTION

"Ultrasonic Coagulation of Phosphate Tailings," by Dr. Dudley Thompson, Assistant Professor Chemical Engineering, has recently been published by Virginia Polytechnic Institute Engineering Experiment Station, as Bulletin No. 75. (Vol. 43. No. 5).—NELSON F. MURPHY,

Virginia Polytecknic Institute.

MEDICAL SECTION

"Factors Influencing Student Success in Medical Education," by A. W. Hurd, has recently been published by the Medical College of Virginia. It is the second study which has been made in the field of student success in medicine.—A. W. HURD, *Medical College of Virginia, Richmond.*

PSYCHOLOGY SECTION

Dr. David Orr was appointed senior clinical psychologist at Eastern State Hospital, Williamsburg, on October 1, 1950. Dr. Orr obtained his Ph.D. in psychology in June, 1950, at the University of Kentucky. He also served for two years as a psychologist at Eastern State Hospital, Lexington, Kentucky.

Mr. Burton R. Wolin has been appointed Assistant Professor in psychology at the College of William and Mary. Mr. Wolin has been doing graduate work at Indiana University, where he completed all requirements for the doctorate in August, 1950, and expects to be awarded his degree next year.

Among the state psychologists attending the annual meeting of the

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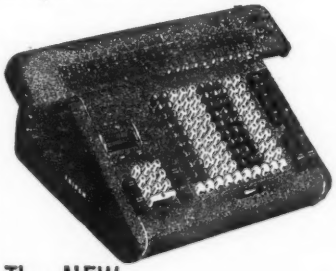

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American Psychological Association held at Pennsylvania State College on September 3-9, were: Dr. John K. Bare, Dr. Stanley B. Williams, Dr. William M. Hinton, Dr. Frank W. Finger, Dr. Richard H. Henneman, Dr. L. Starling Reid, Dr. Frances M. McGehee, Miss Linda L. Carter, Mrs. William Mailer, Miss Patricia Nigg, Mr. Allen Cohen, and Mr. John N. Buck. Dr. Hinton represented the Psychology Section at the meeting of the State Psychological Associations. Mr. Buck participated in two round-table discussion groups. He was chairman of the round table on Ramifications of the H-T-P Technique, and he participated in the round-table discussion on Problems of Mental Deficiency. Miss Carter also participated in the round-table discussion of the H-T-P Technique. Dr. Frank A. Geldard of the University of Virginia was elected President of the Division of Military Psychology.

The present membership of the Virginia Examining Board for Clinical Psychologists consists of: Mr. John N. Buck, Mr. Austin Grigg, Mrs. Catherine T. Giblette, Dr. William N. Hinton, and Richard H. Henneman.

Dr Eugene R. Long of the University of North Carolina returned to the University of Virginia during the summer to participate in the Air Force contract research on visual message presentation. Mr. Ralph W. Queal, Jr., of Washington University, St. Louis, has been appointed

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full-time assistant director of research on the Air Force contract at Virginia.

The Committee on Cooperative Research, whose chairman is Dr. Cecile B. Finley of Hollins College, held a meeting at the University of Virginia on September 14. The functions of this committee were agreed upon as the following:

1. To broaden the knowledge and understanding of the research work being carried on by each of the institutions represented in the section.
2. To make possible more research programs of real consequence in small liberal arts colleges in Virginia.
3. To promote more lively and effective section programs.
4. To increase the interest of all members of the section, especially undergraduate majors, in small cooperative research projects.

Five projects were selected by the committee as an initial program of cooperative research.

Dr. Richard H. Henneman has been invited to report recent research on the intelligibility of speeded speech at a symposium of the Speech Science Section of the Speech Association of America, to be held in New York City the latter part of December.

Miss Hannah S. Davis, formerly of Northampton State Hospital, Massachusetts, has succeeded Mrs. William Mailer as Senior Assistant Psychologist at Lynchburg State Colony. Mrs. Mailer resigned in October to take a position at Traverse City State Hospital in Michigan.

Miss Patricia Nigg, Second Assistant Psychologist at the Colony, will resign in December to take a position in California. She will be succeeded on January 1 by Mr. Allen R. Cohen of Miami, Florida.

The Section treasurer, Dr. Stanley B. Williams of the College of William and Mary, calls the attention of members of the Section to the fact that Academy dues are now payable and should be sent to the Section treasurer, not to the Academy treasurer.

RICHARD H. HENNEMAN, *University of Virginia.*

STATISTICS SECTION

J. Youden has returned from England. He will deliver the winter Sigma Xi lecture at Virginia Polytechnic Institute.

C. M. Mottley delivered the third in a newly instituted series of Statistical Colloquia at Virginia Polytechnic Institute.

Mr. Glenn Suter spent the summer with the Crop Reporting Service at Richmond as Agricultural Statistician, and is now instructing at Virginia Polytechnic Institute.

R. A. Bradley, D. B. Duncan and M. E. Terry attended the Statistical Christmas Meetings at Chicago.

Boyd Harshbarger attended the A.A.A.S. Christmas meetings in Cleveland.

The statistical staff at the University of Virginia, Dr. Rutledge Vining, Mr. Weiss, and Mr. Nicholson, participated in a discussion of statistical programs with the statistical staff at Virginia Polytechnic Institute at Charlottesville on November 12.

All members of the Statistical Section are urged to notify the secretary of news and notes.—M. E. TERRY, *Virginia Polytechnic Institute.*